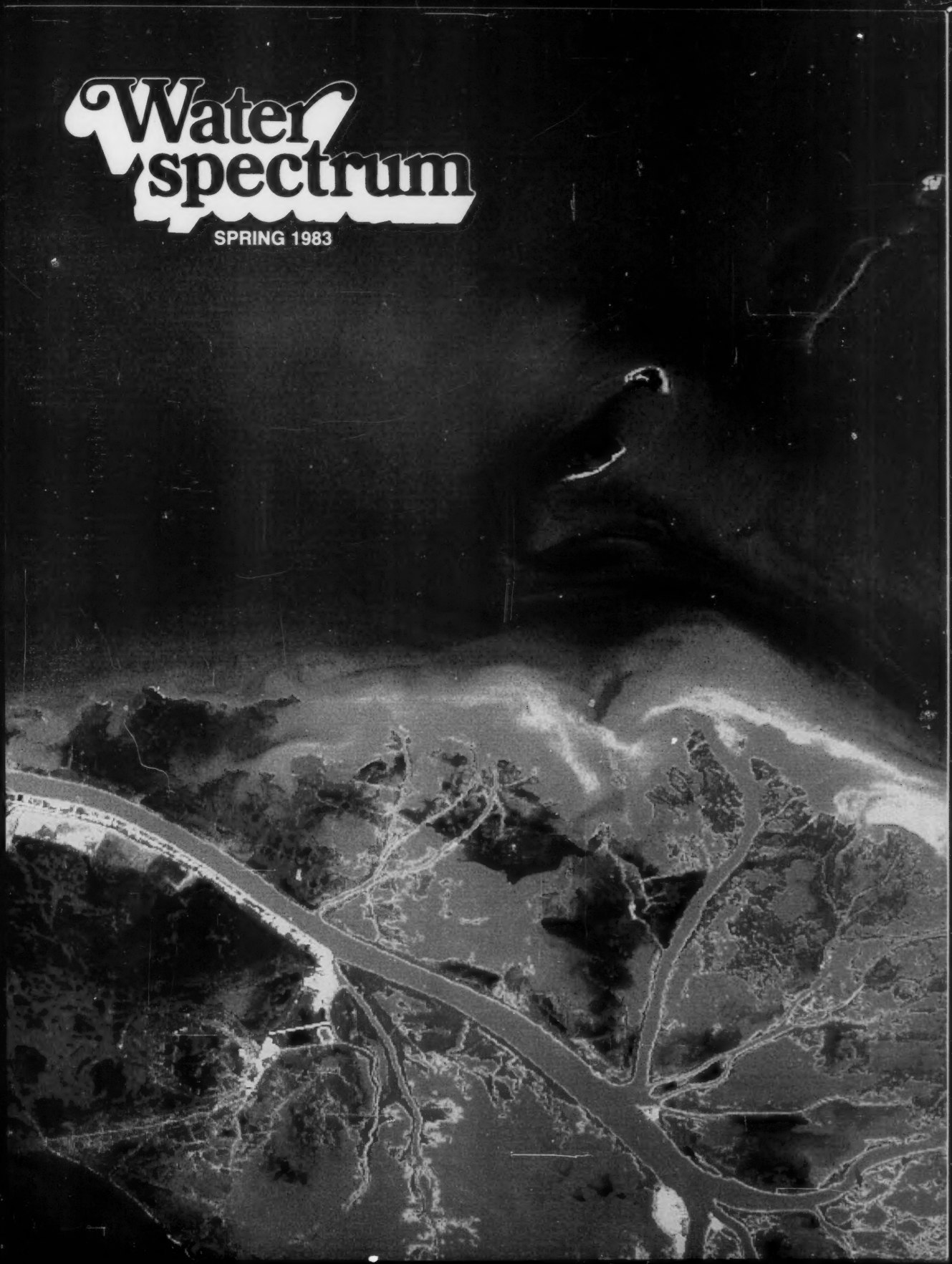
Water spectrum

SPRING 1983



Water spectrum

Published Quarterly | Vol. 15. No. 1 | Spring 1983

Secretary of the Army John O. Marsh

Assistant Secretary of the Army (Civil Works) William R. Gianelli

Chief of Engineers Lt. Gen. Joseph K. Bratton

Director of Civil Works Maj. Gen. John F. Wall

Editor-in-Chief Bob Norton

Editor Joyce Hardyman

Remote Sensing at Work
by Daniel M. Cotter and David E. Lichy
1

Managing Rafting Rivers
by David Berry, Cathy Cox, and Peter Wolff
10

Lake St. Clair: Since the Mercury Crisis
by John H. Hartig
18

Saving an Orchid
by Laura E. Brantley
26

Finding Salmon and Trout in Lake Ontario
by James M. Haynes
30

A Problem Can Be a Resource: Beach Nourishment With Dredged Material
by Mark W. Mugler
38

Events, Deeds & Deliberations
46

Comments on topics in this publication are invited. Send to:
Editor, Water Spectrum
U.S. Army Corps of Engineers
Water Resources Support Center (WRSC)
Fort Belvoir, VA 22060
Letters to authors c/o Editor will be forwarded.

Use of funds for printing this quarterly publication was approved by the Director of the Office of Management and Budget through May 1, 1983.

A major purpose of this publication is to serve as a written forum for the open discussion of issues and choices in resolving water resource problems. Views and conclusions expressed or implied do not necessarily reflect the position of the Corps of Engineers.

Price of a single copy is $3.25. Order directly from Superintendent of Documents, Government Printing Office, Washington, D.C. 20402.

This issue developed by Publications & Training Office, WRSC.

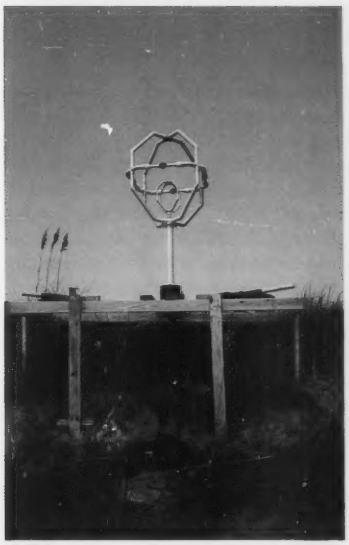
Address changes: Please attach old address label to request for changes.

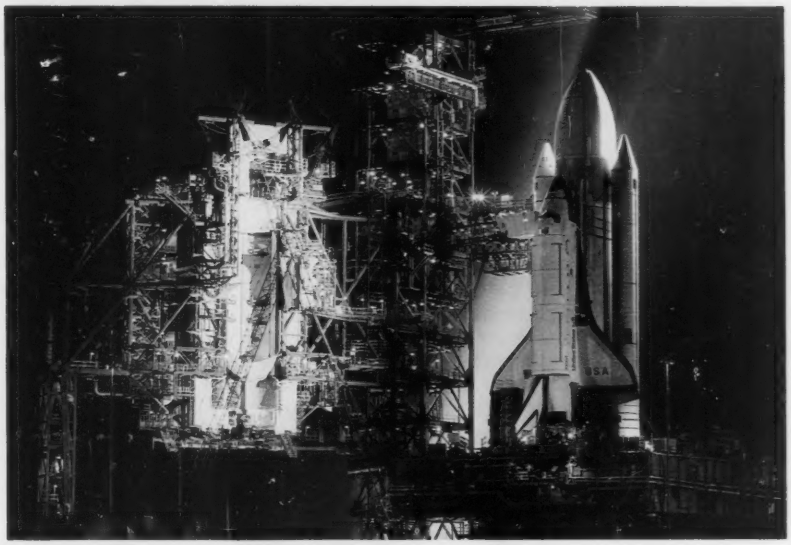
COVER: "The age demanded an image
Of its accelerated grimace"
—Ezra Pound

Cover image courtesy of NASA.

Corps of Engineers Photos

Platforms for remote sensing: satellite (Landsat), aircraft (NASA P-3), ground-based radar, Space Shuttle.





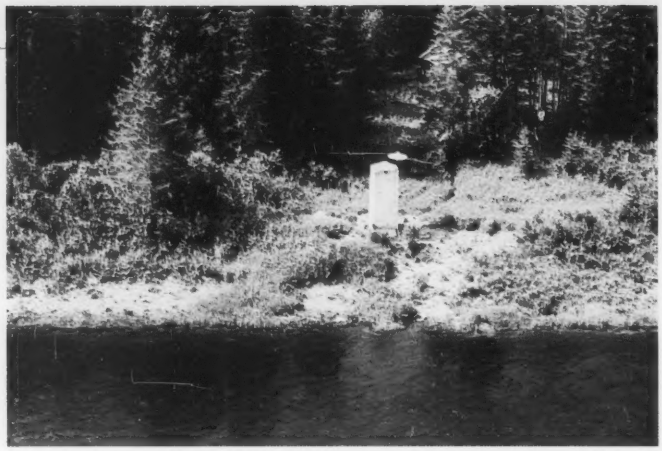
Remote Sensing At Work

by Daniel M. Cotter and David E. Lichy

Remote sensing is the process of collecting observational data about a target without physical contact between the sensor and the target. Information is collected by measuring the electromagnetic radiation reflected or emitted by the target. Humans, with the eye and the brain, are still the most complex remote sensing system that exists. The eye is the sensor, with the body as the platform. The nerves are the transmitter for communications and the brain is the computer for data processing and information extraction.

Present technology consists of many types of sensors that detect more than the light visible to the human eye in various regions of the electromagnetic spectrum. The electromagnetic spectrum is all energy which travels in waves at the speed of light. This continuous spectrum of radiation has several discrete bands; the visible, infrared, and microwave bands are of particular use in data collection, and instruments have been designed to detect electromagnetic radiation in different bands. A number of sensors, each sensitive to a specific band, may be

Mr. Cotter is a hydrologist with the U.S. Army Engineer Topograhic Laboratories, Fort Belvoir, Virginia 22060. Mr. Lichy is remote sensing technical monitor with the U.S. Army Corps of Engineers' Water Resources Support Center, Fort Belvoir, Virginia 22060.



Corps of Engineers

GOES data collection platform, satellite, and receiving station.

grouped together to record data for the same target at the same time. Resolution is the minimum distance required between targets to distinguish them from each other.

Remote sensing is the result of growth in five fields; photography, aircraft, radiation physics, space technology, and computers. The development of remote sensing started with the first fixation of an image photograph in 1839. Aerial photography was well established by World War I and was used extensively for intelligence reconnaissance. By the 1950s radar and thermal-infrared imagery had been developed.

As man progressed from ballons to aircraft and into space, remote sensing accompanied these platforms. The first systematic observations from space were made by the weather observation satellite Tiros 1, launched in 1960. The manned Mercury, Gemini, and Apollo missions produced quality terrain photographs. Apollo 9 and Skylab carried multispectral photography experiments, which were followed by a similar instrument on Landsat, the first permanent platform for gathering high-quality earth resources data. Landsat 1, originally called the Earth Resources Technology Satellite, was launched July 23, 1972, followed by Landsat 2 in 1975, Landsat 3 in 1978, and Landsat 4 in 1982.

APPLICATION IN THE CORPS OF ENGINEERS

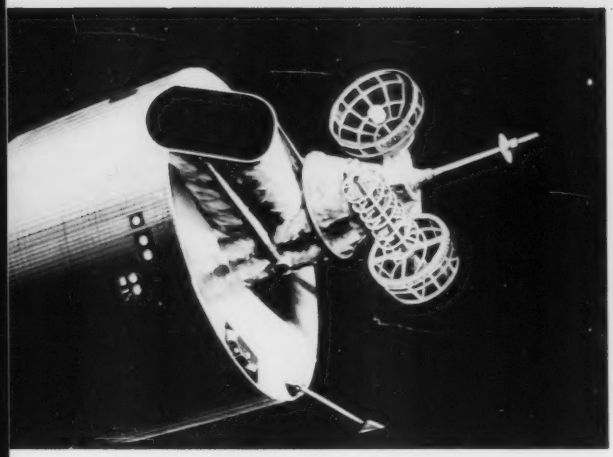
The Corps of Engineers has used remote sensing since the 1930s. In the early years, conventional aerial photography was used for site planning, topographic mapping, project documentation, and engineering design. As the technology evolved, expertise kept pace. In the 1960s and 1970s, new sensors were evaluated and tested. Ground and airborne radars provided coastal, oceanographic, and geologic information. Multispectral scanners, both infrared and visible spectra, were tested over a wide variety of applications, from measuring the effectiveness of thermal insulation in structures to monitoring the dispersion of sediment in water bodies. The 1970s introduced the general use of satellite systems as platforms for remote sensing instruments, and the Corps quickly applied this new dimension of data acquisition to its water resources mission.* In his closing remarks at the Corps' 1981 Remote Sensing Symposium, Major General William R. Wray said, ". . . the potential of remote sensing technology to assist in our mission data requirements seems almost unlimited."

GOES DATA COLLECTION SYSTEM

The Geostationary Operational Environmental Satellite (GOES) data collection system is a good example of the Corps' use of satellite technology. Flood control, in particular, requires real time, or near real time, hydrologic data. River stage and precipitation, the primary parameters, can be acquired by data collection platforms. The data are then relayed via satellite to users.

The data collection platforms are of three kinds. The first are called self-timed and report on a regular schedule, usually every four hours. The second type are interrogated platforms, which are queried when their data are required. The last type are random reporting platforms, which may be either "alert" or "adaptive." Alert platforms are generally programmed to signal the occurrence of an event and do not give continuing reports on the phenomenon. Adaptive platforms are preprogrammed to report when certain parameters reach a critical threshold. Once the threshold has been crossed, the platform

*Two remote sensing symposia hosted by the Corps, in 1979 and 1981, provided many illustrations of remote sensing applications. Several of the following uses of remote sensing by the Corps are documented in the symposia proceedings and are referenced by the primary author's name and the year of the symposium in parentheses.



Corps of Engineers

reports on a pre-programmed schedule until the parameter returns to normal. Corps-wide there are 585 self-timed and 208 random reporting platforms.

An example of adaptive random reporting platforms' usefulness is the collection of floor hydrograph data. The platform can be programmed to report once every four hours, except when a certain threshold evaluation is crossed. The platform will then report more frequently, as often as once every few minutes if necessary, until the flood wave has passed.

New England Division has done much work in the development and operational use of data collection platforms (Buckelew, 1981). In the early seventies the division conducted tests using Landsat 1 and has since implemented ground systems, including a receiving station and computer processing of data. New England Division's Reservoir Control Center can use real time data from over 40 platforms to aid in operation of 35 dams and four hurricane barriers.

GEOMORPHIC ANALYSIS

Information about landforms and regional tectonics can be derived from the analysis of Landsat imagery. The Cold Regions Research Engineering Laboratory (Gatto *et al*, CRREL Report 80-4, 1980) in coordination with Alaska District, studied the Upper Susitna River Basin using Landsat images as the base source for analysis. Maps and interpretations were compiled solely from Landsat imagery before being compared to results from aerial photography, field data, and published reports.

The Upper Susitna Basin lies in the southeastern quarter of Alaska, about 250 miles north-northeast of Anchorage. It is a rugged, remote region, with harsh winters. Records for 20 stations show an average 70 percent cloud cover over the region. (Cloud cover is a major limitation in Landsat imagery.)

The study was divided into three parts: mapping drainage patterns, evaluating geologic lineaments, and mapping surficial materials. In all three cases Landsat imagery was analyzed before any other type of data was studied. Manual photo interpretation techniques demonstrated the usefulness of Landsat imagery without the need for sophisticated equipment. Mapping was done at the 1:250,000 scale.

Black and white Landsat images of bands 5 and 7 were used to map the drainage networks. Band 7 showed water areas and shorelines more clearly than any other band. In some cases, when water surfaces were not visible, streams were inferred from landforms or vegetation patterns. Braided channels, glacial outwash plains, mid-channel bars, and islands in the Susitna River were apparent in the images. For the most part, the drainage pattern of the basin was dendritic. There was an area of radial drainage in the center of the basin and a small area of parallel drainage in the upper basin. Besides the basic hydrologic information provided by drainage network mapping, geologic information could be inferred from the drainage pattern. Slope, bedrock variations, structural conrols, recent tectonism, and the geomorphological history of the basin influence the geometry of the watercourses.

Lakes, glaciers, and snowfields were also mapped from the Landsat imagery. Lakes as small as 100 meters in diameter and 8000 square meters in surface area could be mapped. Smaller lakes were visible on the imagery but were too indistinct to be mapped. The glaciers and snowfields were most easily mapped from a color composite, where ice appears blue and snow, white. Distinguishing snowfields from some small glaciers was difficult because snow covered the ice.

Lineaments were mapped at the 1:250,000 scale using cloud-free band 7 Landsat multispectral scanner images. Many lineaments were readily apparent in the image, but only those features associated with reported regional tectonics were mapped. The resulting map showed a primary and a secondary set of lineaments, which were confirmed by the literature, field checking, and aerial photography.

Six surficial geologic units were also mapped. Tonal and textural differences indicated the spatial extent of the various units. Field checking of the results indicated that exposed bedrock regions could be accurately mapped, but areas of unconsolidated sediments could not be clearly defined.

NATIONAL DAM INVENTORY PROGRAM

In 1972 the Corps was asked to conduct the National Dam Inspection Program. Public Law 92-367 required the Corps to inspect and inventory all dams at least 25 feet high or with storage capacity greater than 50 acre feet. The smallest dam requiring inspection under this act is 26 feet high with a 16 acre-foot impoundment. Landsat was used as a uniform, nationwide method of locating dams for the inventory, and can be used to update the data base.

The experience of Chicago District (Dumas, 1979) in using Landsat demonstrates that the system can detect impoundments other methods may miss. The shortcomings of the Landsat system are that it may fail to detect some small impoundments and bodies of very turbid waters. To close this gap, Landsat data are supplemented by aerial photography and local information. Currently, 68,153 dams are contained in the inventory.

Corps of Engineers

LAND COVER CLASSIFICATION

The multispectral nature of Landsat imagery makes it possible to map areas of different land cover. These data are of interest to the Corps because the runoff potential of a watershed can be estimated from land cover data. Hydrologic models make use of this type of information.

The digital form of Landsat data allows it to be analyzed by computer. The University of California has developed for the Corps a system that can classify land cover from the digital Landsat data (HEC, Research Note No. 7, 1979). This system is referred to as the UCD Procedure.

The procedure has been demonstrated at five sites including Walnut Creek in Fort Worth District and Pennypack Creek in Philadelphia District. The Hydrologic Engineering Center compared land cover data derived from the UCD Procedure with data compiled and stored in grid cell format by the districts.

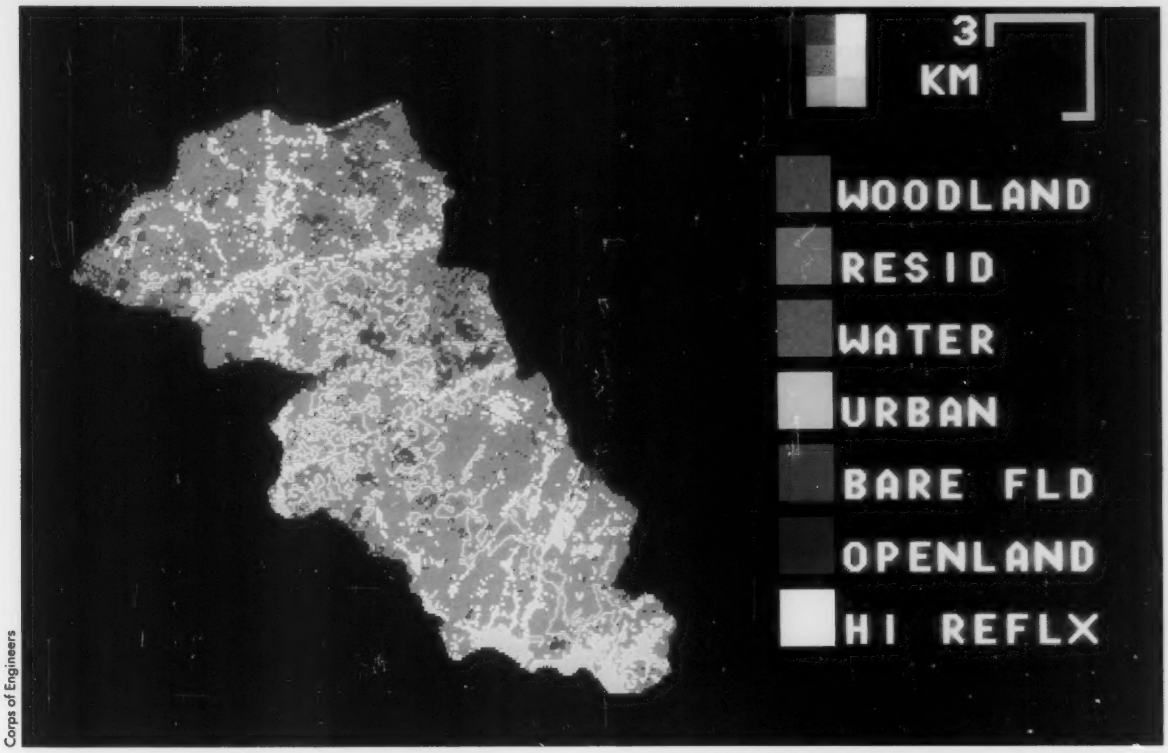
The Landsat data are collected by the multispectral scanner in the form of a pixel, a rectangular shape which represents the smallest element on an image. The pixel covers an area of about 1.1 acres on the ground for multispectral scanner and .25 acres for the new thermal mapper launched in July 1982. The spectral value assigned to a pixel represents an average or dominant value. This means that there could be several types of land cover within a pixel but only one spectral value would be recorded. The types of land cover that are differentiated by Landsat imagery may be inconsistent with conventional classification systems. These are problems in determining the accuracy of the UCD Procedure.

The grid cell sizes used in the studies were relatively close to Landsat pixel size, between .74 acre and 1.53 acres. At the level of an individual grid cell, one-third of the grid cells were misclassified by the procedure; but, when looking at major land classification categories and at the scale of a watershed, accuracy improved to two to eight percent error, acceptable for the needs of hydrologic modelers. When the Landsat land cover data were used to calculate discharge frequency curves, the Hydrologic Engineering Center found differences between conventional and Landsat-derived frequency curves to be insignificant.

AIRBORNE LASERS

Lasers can be mounted on aircraft and used to collect topographic and bathymetric data. By knowing the altitude of the aircraft and measuring the time required for a laser pulse to travel from the ground and be reflected back, the ground elevation can be calculated. Depending on the configuration of the system, the laser can measure a topographic profile or scan a swath of terrain data. Elevation data are a critical part of geographic data bases used in computer simulation for water resources planning and operations. These elevation data are 10 times as costly to collect as other types of terrain data (Bailey, 1981).

Landsat image of Susitna River.



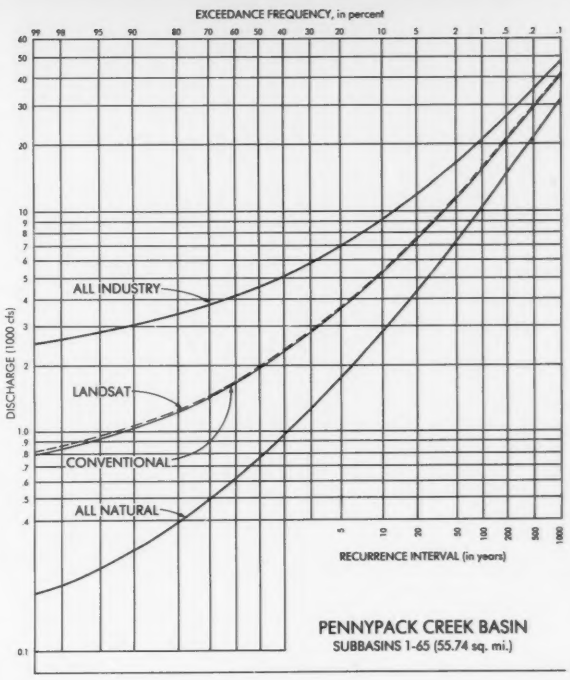
Corps of Engineers

Automated land cover classification from Landsat image, Pennypack Creek.

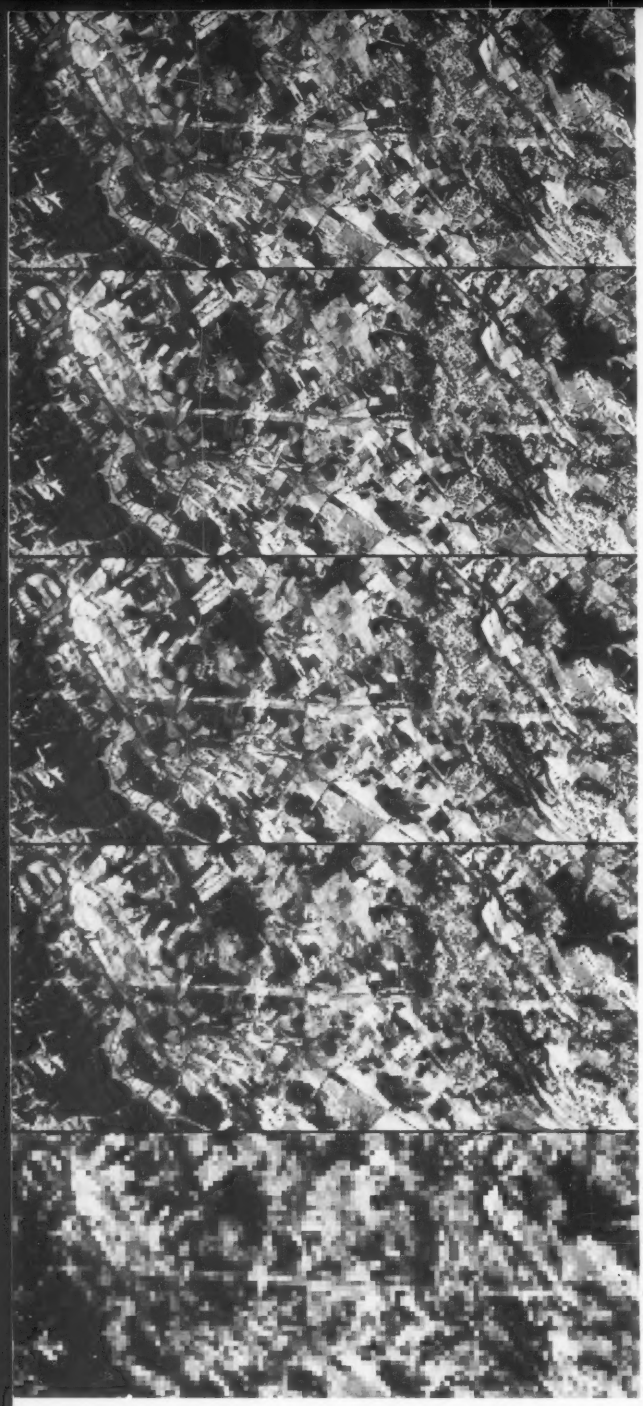
Wilmington District has applied this technology in a demonstration project conducted with the National Aeronautics and Space Administration (Boone, 1981). The NASA airborne oceanographic LIDAR (light detecting and ranging), a laser system, was applied to shoreline mapping, inlet and channel bathymetry, and beach restoration. Data were collected at 0.5 meter intervals over the beach and near shore region in both swath and profile modes. Data in the nearshore region were collected at water depths of 0.5 to 6.0 meters.

The high speed of collecting data with this type of system is particularly advantageous in coastal regions where terrain is in a constant state of change. Mapping submerged features by conventional techniques, particularly when there is wave action or sudden changes in elevation, is difficult. Results from the demonstration project indicate that mapping by airborne laser may provide an easier, more accurate way of collecting these data.

The Waterways Experiment Station has conducted several experiments in the use of airborne lasers for topographic mapping (Krabill, 1981; Bailey, 1981). Data were acquired


EXCEEDANCE FREQUENCY, in percent
99 98 95 90 80 70 60 50 40 30 20 10 5 2 1 .5 .2 .1
DISCHARGE (1000 cfs)
60 50 40 30 20 10 9 8 7 6 5 4 3 2 1.0 9 8 .7 .6 .5 .4 0.1
ALL INDUSTRY
LANDSAT
CONVENTIONAL
ALL NATURAL
1 5 10 20 50 100 200 500 1000
RECURRENCE INTERVAL (in years)
PENNYPACK CREEK BASIN
SUBBASINS 1-65 (55.74 sq. mi.)

Comparison of frequency discharge curves computed from conventional and computer-generated land cover data.



Courtesy of GeoSpectra Corporation

Effects of varying spatial resolution.

over Wolfe Creek River Valley near Memphis, Tennessee, and over four sites in Louisiana. Measurements were taken in both winter and summer to determine the effect of foliage on the system.

The profile data collected during winter at the Wolfe Creek site were compared with results from photogrammetry and ground surveys. There was a root mean square agreement of 12 to 20 centimeters. Summer data, when trees were in full foliage, produced a 50-centimeter root mean square agreement with photogrammetry.

At the Louisiana test site data were collected with accuracies ranging within plus or minus 0.5 meters. The cost of acquiring and processing the topographic data collected by airborne lasers was one-third the cost of data acquisition by photogrammetric or field survey methods.

MISCELLANEOUS APPLICATIONS

Corps studies have combined several remote sensing techniques as quick and as inexpensive means of collecting data. San Francisco District (Shieh, 1981) has explored the application of remote sensing to coastal and estuarine problems. Environmental data on surface temperature, vegetation density and type, currents, waves, wetlands, turbidity, and shape of water features were collected. This information was compiled mainly from aerial photography, but thermal scanners, Landsat multispectral scanners, Skylab and side-looking airborne radar imagery were also used. Wave refraction was imaged on color film by U-2 aircraft. Infrared scanners also provided information on wetlands, water bodies, and plant types. In particular, multispectral scanners were used to analyze plant types and densities. The spectral signatures of differing plant communities were imaged by using four different types of film: blue, overexposed yellow filter color, near infrared, and color infrared. The results of this study demonstrate the viability of remote sensing as a collection tool for coastal environmental data.

Tulsa District (Hill, 1981) used color infrared aerial photography to map vegetation communities in the Little River, Cossatot River, and Pond Creek bottoms in Sevier County, Arkansas. Twelve different communities were mapped in a study area of about 44,000 acres. Color infrared imagery was gathered in two overflights, in October 1980 and March 1981, at a scale of 1:12,000. The data were verified by U.S. Geological Survey 1:24,000 scale maps and ground truth from field trips to study areas. The October imagery was used to map open areas, while the March imagery was more useful to distinguish the primary forest communities. In some instances both sets of imagery were needed to make a classification. All vegetation categories were mapped with an accuracy of 97 percent. The study found that field-checked 1:12,000 color infrared fall and spring imagery provided enough information to map vegetation communities in the area.

Portland District (Dodge, 1979) has used aerial photography to monitor the disposal of dredged material in accordance with the Federal Water Pollution Control Act Amendments of 1972. Section 404 of that act requires the Corps to regulate the discharge of dredged or fill material into the waters of the

United States. The district has used comparisons of existing photography with current photography as a means of easily detecting change. Areas where change is noted are then scheduled for field inspection. This procedure eliminates the need to visit areas that have no significant activity or are difficult to reach. Portland District has used a number of photographic scales and formats for this task, but found color infrared film at the 1:24,000 scale to be the most effective.

COMPUTER TECHNOLOGY

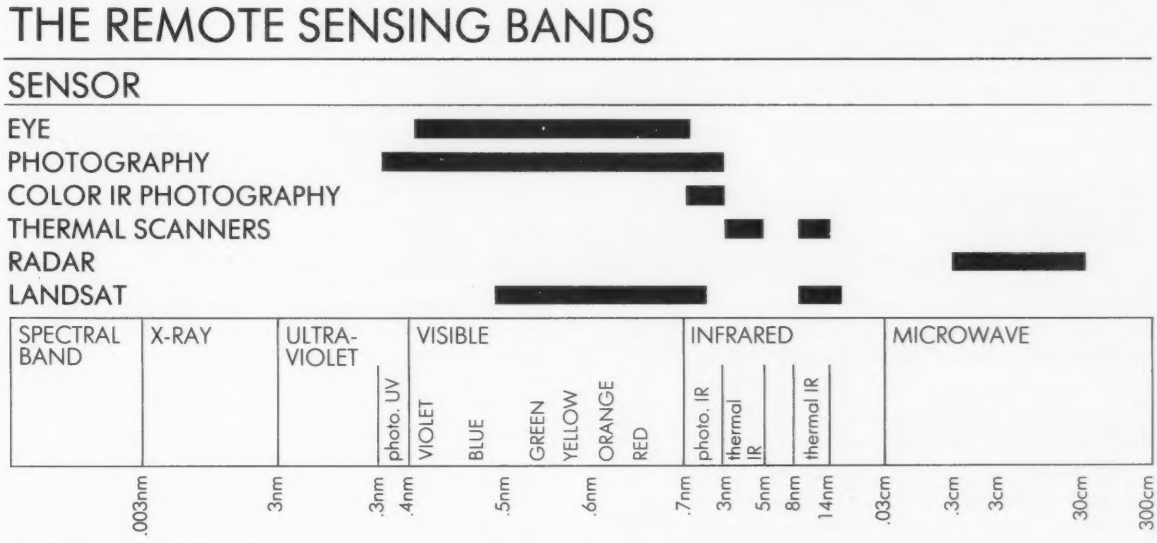
The ability of computers to handle large volumes of data and to perform repetitive, iterative calculations at high speed make them indispensable tools for handling remotely sensed digital data. The spatial, rather than point, nature of much remotely sensed data is complementary to the development of grid cell data bands. The hydrologic Engineering Center has developed such techniques in its spatial analysis methodology studies such as the Pennypack Creek study in Philadelphia District. These spatial data management techniques are beginning to be used regularly by the Corps.

Grid cell data bases are a computer "map" of a region. The map is composed of small rectangles, called grid cells, the size of which the user determines by the accuracy needs of his project. Each grid cell contains a piece or pieces of information which is an average or dominant value for that discrete section of the map. Several pieces of information may be stacked on top of each other in each grid cell. This is analogous to map overlays, with each overlay displaying a different type of information. There are various methods of encoding grid cell information, from hand compilation to the use of automatic digitizing machines.

Buffalo District (Adams, 1981) developed the Land Resources Information System, a grid cell data base of land use, soil, minor watersheds, and political subdivisions for the 22,000 square miles of United States drainage into Lake Erie. The land use data were compiled from color infrared photography. The data were digitized and encoded into the data base. One use of this data base is the computation of potential erosion. The analysis of the data base provides accurate maps showing erosion rates. Scenarios of erosion rates under differing conditions can be compared to determine the best and most cost-effective method of managing land to reduce soil losses.

Vicksburg District (Hudson, 1979: Wilcox, 1979) has used computer grid cell data bases with remotely sensed information to develop stage area tables for the Yazoo Backwater Area and historical trend analysis of land-clearing activities within the discrete flood zones of the Tensas River project. In both cases a digital data bank was created by digitizing maps to form an elevation data base which was then overlaid by digital Landsat information. Other information—land use and cover, soil type, economic factors—could also be overlaid onto the data bases. For both studies satisfactory stage area tables were developed. In the Tensas River project the data base also allowed the development of an analysis on the effect of a flood-control project on land clearing. In both cases, the cost of future studies will be significantly reduced because the initial high-cost work of digitizing elevation information and creating the spatial data base is completed. These data bases will also be easy to update with Landsat data.

Rock Island District has demonstrated the applicability of a grid cell data base combined with digital Landsat information for floodplain management in the upper Mississippi River. The district's work has shown that floodplain vegetation maps can be updated without the need for costly surveys.



The electromagnetic spectrum.

The Rock Island District also applied this methodology to the development of a dredge disposal suitability analysis of the region. In addition to land cover, distance from the river and location of the bluff (to avoid pumping material uphill) were chosen as typical criteria. The bluff line was digitized from the USGS topographic quadrangle. Relative weights, indicating importance and desirability of the values for each feature, were chosen. These were combined to create a sample map indicating the most desirable disposal sites for dredging performed within this area. One of the major advantages of this method lies in the digital form of the data; land cover and other factors can be updated easily and weights can be customized to each site relatively simply.

OTHER PROGRAMS

Besides the field applications, the Corps of Engineers' work in remote sensing consists of research, demonstration, and training programs. The research program evaluates remote sensing technology to meet data collection needs and develops new methodology for processing and integrating remotely sensed data into the mainstream of Corps functions. The objective of the program is to provide rapid, cost-effective collection and use of data. Work is being funded at Corps laboratories, with the research tailored to their areas of technical and environmental expertise.

The remote sensing demonstration program is a cooperative one among the Corps laboratories, field offices, and other agencies to demonstrate remote sensing applications using specific Corps projects as test sites. The purpose of demonstrations is to facilitate and encourage the application and assessment of remote sensing as a data collection tool for the Corps. Currently, there are remote sensing demonstration projects under way in the North Central Division and the Ohio River Division.

The training program consists of courses, symposia, and workshops to assist field office personnel in developing a working knowledge of remote sensing. The Corps sponsors, through the Huntsville Prospectives program, four courses on fundamentals of remote sensing, remote sensing for managers, digital processing, and photo interpretation. The combination of demonstration, applications, research, and training programs will enable the Corps to fully utilize remote sensing technology in its water resources management mission.

FUTURE SYSTEMS

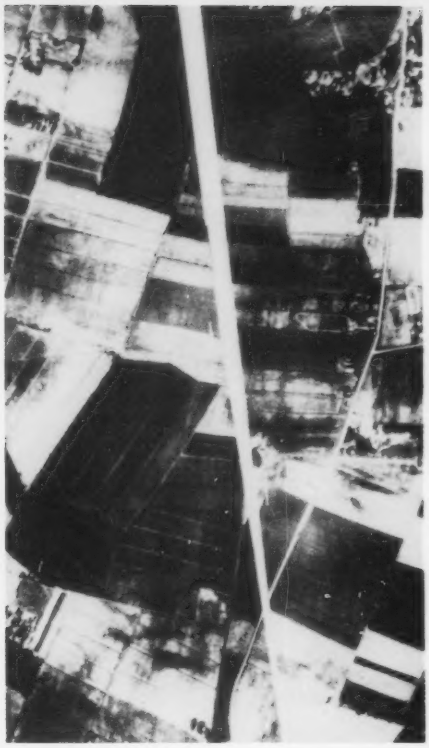
The United States launched a new Landsat, Landsat D, in July 1982. This system carries a multispectral scanner and a new instrument called a thematic mapper. The mapper will provide multispectral data at 30-meter resolution, as opposed to the 80-meter resolution of the multispectral scanner. The mapper will also provide data in six spectral bands, from blue to infrared, and a thermal infrared band with 120-meter resolution. A second satellite in this series, Landsat D, is planned and should provide continuity of data until 1988. Various satellites are being planned after Landsat D (the government is encouraging the commercial sector to become more involved with the program).

Corps of Engineers

Color infrared photography, black and white photography, thermal infrared, and synthetic aperture radar imagery covering the same area at the same scale. Test site is near Elizabeth City, North Carolina.

The Space Shuttle program will also have experimental earth resources remote sensing payloads. Several experiments were conducted on the second Space Shuttle flight of November 1981. Included on this flight were a multispectral infrared radiometer, an air pollution instrument, an ocean color experiment, a feature identification and location experiment, and SIR-A (shuttle imaging radar), a synthetic aperture radar. A new radar, SIR-B, is planned for future flights.

The Center national d'Etudes Spatiales, in France, is developing an earth resources spacecraft, planned for 1985 launch. This spacecraft, called SPOT (Systems Probatoire d'Obscervation de la Terra) will carry a three-band multispectral scanner with 20-meter resolution. A SPOT II mission is also planned, and, depending on the performance, SPOT III and SPOT IV missions will be considered. □



SOURCES OF INFORMATION AND IMAGERY

Much of the information about Corps applications of remote sensing in this article came from the 1979 and 1981 symposia. Some general sources of information include the following: *Remote Sensing Applications Guide* (EP 70-1-1, 1979), published by the Corps of Engineers; The *Manual of Remote Sensing*, published by the Society for Photogrammetry and Remote Sensing; *Satellite Hydrology*, published by the American Water Resources Association; and *Remote Sensing, Principles and Interpretation* (W.H. Freeman and Company, San Francisco, 1978), by Floyd F. Sabins, Jr. Other sources include periodicals like *the Journal of Photogrammetric Engineering and Remote Sensing*. Literature searches of computer library information systems such as the National Technical Information Systems (NTIS) are an efficient means of locating references. This type of literature search can be conducted, upon request, by Corps libraries. Some topics to search under are remote sensing, type of application, type of sensor, and geographic location. There are volumes of material on remote sensing applications and much of it is contained in the computer library information systems, through which literature searches are easy and inexpensive to perform.

The National Cartographic Information Center (NCIC), part of the U.S. Geological Survey, archives aircraft and space imagery. Aircraft black and white, color, and color infrared photos are available. NCIC also has manned spacecraft photography from Apollo, Gemini, and Skylab missions. Landsat data can be obtained from the Earth Resources Observation System (EROS) data center. EROS is part of NCIC. Computer searchers are conducted by EROS to locate Landsat scenes meeting user requests. Further information on costs, search and inquiry systems, available imagery, and ordering products can be obtained by writing:

National Cartographic Information Center
U.S. Geological Survey
507 National Center
Reston, VA 22092

The Corps has an account with EROS for the purchasing of Landsat imagery. For further information, contact:

Water Resources Support Center
Remote Sensing Technical Monitor
Kingman Building
Ft. Belvoir, VA 22060

NOAA maintains the archives for the meteorological satellites and administers the GOES DCS program. For more information on the kinds of imagery stored by NOAA or on the GOES DCS, write:

Satellite Data Services Division
NOAA/EDIS/NCC
World Weather Building, Rm. 100
Washington, DC 20233

Managing Rafting Rivers

Ed Deaton/Pennsylvania Bureau of State Parks

by David Berry, Cathy Cox, and Peter Wolff

In the past few years, several hundred thousand people have splashed into rivers in the northeast in inflatable rafts. Many of these adventurers were transported by commercial outfitters through violent and dangerous whitewater. As more and more people seek float trips or furious rapids, canoe outfitters, outdoorsmen, and small businessmen have been able to take advantage of a rapidly growing market by offering a new service with only a limited capital investment. Rapid growth of commercial rafting has also presented river recreation management problems to states, and management studies are now under way in West Virginia and Pennsylvania to help officials cope with increasing numbers of rafters.

This article analyzes the factors affecting the volume of commercial rafting in the northeast (West Virginia to Maine), and reviews the major management considerations resulting from high volumes of rafting traffic. Rafting in the northeast has not been studied in any comprehensive way, and yet conflict situations arising from large-scale rafting are now beginning to face recreation and natural resource agencies. Hence, an overview of the activity and its effects is needed, especially considering the prevalence of rafting on scenic rivers in primitive woodland environments.

In the past few years, several hundred thousand people have splashed into rivers in the northeast in inflatable rafts.

The authors are with Abt Associates, a social science research firm in Cambridge, Massachusetts 02138.

EXTENT & NATURE OF RAFTING

In the northeastern United States rafting rivers fall into three use categories. Those rivers which offer violent whitewater and which regularly provide recreation for a large number of persons are *adventure rivers*. A trip down one of these rivers takes from a half-day to two days, depending upon the availability of whitewater and the demand for short or long trips. Most trips typically take six to eight hours, including launching time and breaks. Class IV and V rapids and sometimes Class VI rapids are present on adventure rivers, and these provide the excitement people are looking for. Adventure rivers in the northeast are the Cheat, New, and Gauley in West Virginia; the Youghiogheny and Lehigh in Pennsylvania; the Indian-Hudson in New York; and the Kennebec and West Branch of the Penobscot in Maine.

In contrast, *family rafting rivers* usually offer half-day trips on rivers that include little violent whitewater; Class II and III rapids generally are the most difficult encountered. These float trips can be enjoyed by children and older people. They are offered commercially on the Shenandoah in West Virginia and on the Sacandaga in New York. In addition, float trips are offered on the Lehigh during low flow in the summer months and on the upper part of the New River in West Virginia.

Occasional use rivers typically have violent whitewater but are rafted only a few times per year. These include the Moose River in New York, the West River in Vermont, the Dead River (Kennebec watershed) in Maine, the Tygart and Greenbrier rivers in West Virginia, Pine Creek in Pennsylvania, and the Upper Youghiogheny in Maryland, among others. These rivers may have only a few weeks of suitable flow for rafting, so they are not heavily used. Some may also be potential candidates for adventure rivers as demand for rafting increases and as operators become more familiar with navigating them.

Northeastern rafting provides two very different experiences for the recreationist. One is the excitement of paddling through violent rapids and of holding onto the raft while negotiating difficult whitewater. This activity demands the full attention of the rafter for successful navigation. But in quieter stretches of river or on the shore, the scenic aspects of the trip become dominant. The riverscape is typically primitive, having only a few signs of human activity such as roads, bridges, an occasional town or settlement, and power lines. Most of the view is of water, forest, gorges, hills, or mountains. Thus, the views that one may have on a rafting trip range from unbroken forest, mountains, or a gorge to occasional pockets of commerce or transportation. The greatest aesthetic intrusion is likely to be strip mines.

For the expert, adventure *rivers, with their Class IV, V and VI rapids, can definitely provide a challenge.*

Photo courtesy of Class VI River Runners

Ed Deaton/Pennsylvania Bureau of State Parks

Estimating the quantity of passengers carried by commercial outfitters on most of these rivers is quite difficult. Except in a few cases where passengers have to pass through checkpoints or are otherwise counted, estimates must be based on interviews of outfitters and state officials who may have no reliable records or who may be reluctant to divulge business information. *Table 1* summarizes the estimates for the adventure rivers. Even as river management issues increase in importance, few good records are kept on this activity.

Estimating the quantity of passengers carried by commercial outfitters is difficult.

TABLE 1: *Estimates of Passengers on Adventure Rivers in the Northeast*

River	Passengers in 1981	Data Sources
Adventure Rivers		
• Cheat	40,000	State officials, outfitters
• New	60,000-80,000	State officials, outfitters
• Gauley	25,000	State officials, outfitters
• Youghiogheny	61,500	Ohiopyle State Park records
• Lehigh	39,000	State officials, outfitters
• Indian-Hudson	3,000-4,000	Outfitters
• Kennebec	7,000	Outfitters
• West Branch, Penobscot	8,000	Outfitters

TABLE 2: *Factors Affecting the Volume of Rafting in the Northeast*

	FACTOR					
River	Gradient (feet per mile)	Number of Months Where Average Flow Exceeds 1000 cfs (March-October only)	Year First Rafted Commercially	Months When Most Rafting Occurs	Proportion of Passengers on Weekends	Population Living Within 300 Miles of River (in millions)
Adventure Rivers						
• Cheat	18	6	1972	April-June	85%	57.6
• New	12	8	1969	April-October	60%	43.3
• Gauley	26	4-5	1974	September-October	50%	43.3
• Youghiogheny	24	8	1963	April-October	75%	59.6
• Lehigh	24	4-5	1967	March-May, October	75%	62.7
• Indian-Hudson	36	1	1978	April	70%	46.1
• Kennebec	18	8	1975	late May-September	60%	13.5
• West Branch, Penobscot	18		1977	late May-September	87%	9.9
Family Rafting Rivers						
• Shenandoah	11	8	1971	April-October	50%	58.0
• Sacandaga	16	6	1978	April-October	50%	49.0

Sources of data:
Gradient: U.S. Geological Survey topographic sheets.
Flow: U.S. Geological Survey gauging station records for stations located as close as possible to rafted areas; upstream and downstream stations examined if none in rafted areas; data are from late 1970s.
Year first rafted commercially, months when rafting occurs, and proportion of passengers on weekends: interviews with outfitters, outfitters' brochures, and state officials in West Virginia and Pennsylvania.
Population: U.S. Bureau of the Census, 1980 Census of Population and Housing Advance Reports for counties within 300 miles of the river, straight-line distance. Counties are included only if at least one-half their land area is within 300 miles of the river. Canadian populations from Rand McNally Road Atlas.

Several factors bear upon the volume of passengers carried on the adventure and family rafting rivers. (Table 2)

- The availability of violent whitewater for adventure rafting. The average gradient of the river can be used as a summary measure of the presence of whitewater. The adventure rivers provide a steep gradient while the family rafting rivers offer a gentler gradient. The New River, although having a rather modest gradient, makes up for this with an impressive rate of discharge, often over 10,000 cubic feet per second. Gradient is a crude measure of the presence of whitewater, however, and more detailed descriptions of the rivers may be found in guides such as that by William McGinnis (*Whitewater Rafting,* New York: Times Books, 1975); Bob Burrell and Paul Davidson (*Wildwater West Virginia,* Ann Arbor: Thomas Press, 1975); and the Appalachian Mountain Club (*AMC River Guide, Volume I: Maine,* Boston: Appalachian Mountain Club, 1980) as well as in some outfitters' brochures.
- The number of raftable days. Depending upon temperature and river flow, the rafting season runs from one month to eight. In addition, the proportion of all passengers rafting on weekends and holidays affects annual use. Weekend factors vary from 50 percent to about 90 percent.
- The process of supplying increasing demand by bringing additional rivers into service. This has tended to reduce congestion and has extended rafting to more rivers. The Lehigh, New, and Youghiogheny have all been rafted since the 1960s. Other rivers have been added since then to accommodate increasing demand.
- The presence of substitute rivers. If there are several rivers to choose from all close together, then demand may be spread over them, affecting the use levels of all of them. The extent of this effect is not known, however, given the scarcity of data on use.
- The population of the "market area" of the river. Since most rafters participate in this activity on weekends, a rough market area can be delineated around any river by a circle whose radius is 300 miles, about a one-day trip to the river. Some rafters come from farther away, of course, but 300 miles is a convenient distance for delimiting the primary service area of a river. Populations within 300 miles vary enormously—from about 10 million persons within a day's drive of the West Branch of the Penobscot to over 60 million within a day's drive of the Lehigh.

The rapid growth of commercial rafting has put pressure on the land along the rivers and generates conflicts with other recreation activities.

Family rafting rivers also take advantage of other attractions close by the river, since a brief float trip is probably insufficient inducement to travel very far. Harper's Ferry National Historical Park, Civil War battlefields, and famous scenery are close to the Shenandoah; the Adirondacks, Lake George, Saratoga, and Revolutionary War battlefields are near the Sacandaga.

The following index summarizes the attractive power of the adventure rivers in passengers per rafting month per one million persons living within a day's drive. For example, an index of 200 indicates 200 passengers per rafting month per one million persons living within a day's drive of a particular river.

Attraction indexes for 1981 for the adventure rivers are as follows:

Indian-Hudson Rivers:	65-87
Youghiogheny River:	147
Lehigh River:	156
Kennebec River:	115
Cheat River:	231
New River:	198-264
West Branch	180
Gauley River:	289

Several rivers have high attraction indexes: the Gauley, the New, and the Cheat all attract over 200 persons per rafting month per one million population. The West Branch, Kennebec, Lehigh, and Youghiogheny are slightly less intensively used. The Youghiogheny has binding use limitations, and the Kennebec has no Sunday rafting because of low flows. It is not clear why the Lehigh is not used more. The Indian-Hudson is now "underused" and outfitters are planning for increased use in 1982.

Future use of these rivers will depend upon how rapidly demand for rafting grows, both by first-time rafters and by repeaters. Since only the Indian-Hudson seems to be lagging greatly in intensity of use, there is no obvious candidate to absorb a lot of additional growth. It is likely that increased demand will be satisfied by bringing another river into "production." Given the distribution of population, the river is more likely to be in southern New England, New York, New Jersey, or Pennsylvania than in northern New England. This additional river would have to provide several months of rafting—unlike the Indian-Hudson—in order to accommodate a significant proportion of increased demand generated in the northeast.

Northeastern rafting provides two very different experiences for the recreationist. One is the excitement of paddling through violent rapids and of holding onto the raft while negotiating difficult whitewater; but in quieter stretches of the river or on shore, the scenic aspects of the trip become dominant.

Management Considerations

The rapid growth of commercial rafting has put pressure on the land along the rivers and generates conflicts with other recreation activities. To minimize these conflicts, land use and recreation agencies must consider the factors affecting the carrying capacity of the river. These management factors fall into five categories.

1. ***Launch and take-out characteristics.***

Experience with put-in and take-out points indicates that handling more than four launches of three or four rafts each per hour at a single site is logistically difficult. Vehicles (buses and trucks) must be maneuvered, rafts put into or taken out of the water, passengers loaded or unloaded, and instructions given. Depending upon river characteristics, rafts hold from four to 12 passengers. Thus, congestion at launch sites will be affected by raft size.

John S. Tilney, Jr/Abt Associates

2. *Launching hours.*

The number of launches per day depends upon the time required to make the trip. It is desirable to have trips run entirely in daylight, so a seven-hour trip in the summer could not start after about 1 p.m. Trips generally cannot start before about 7:30 a.m., since passengers must be assembled at the put-in point. Thus, launching hours are generally from 7:30 a.m. to 1 p.m., except for half-day trips.

3. *Number of "raftable" days.*

The number of weekends days and holidays per rafting season is a constraint on use. As the season lengthens or as the weekend factor decreases, more passengers per year can be served. Where dams do not provide suitable flow on some days, it may be possible to negotiate with the dam operator for the release of a "bubble" of water for recreational use to divert some rafting away from crowded days.

As rivers become more congested, there is a tendency to impose limitations on daily use.

4. *Lunch or break site factors.*

A day-long trip will require at least one break for lunch. Assuming that a party stays at the lunch site for an hour and wishes to be undisturbed, at least as many lunch sites as launches per hour are necessary. With over 100 rafters per lunch site per day, sanitation facilities are generally needed to prevent water pollution. In addition, to minimize ecological damage from crowds of rafters, lunch sites should be well defined, perhaps with fences or barriers. Picnic tables, fireplaces, parking for service vehicles, a raft-beaching area, and toilet facilities with a septic tank or other provisions are minimal requirements on high-volume rafting rivers.

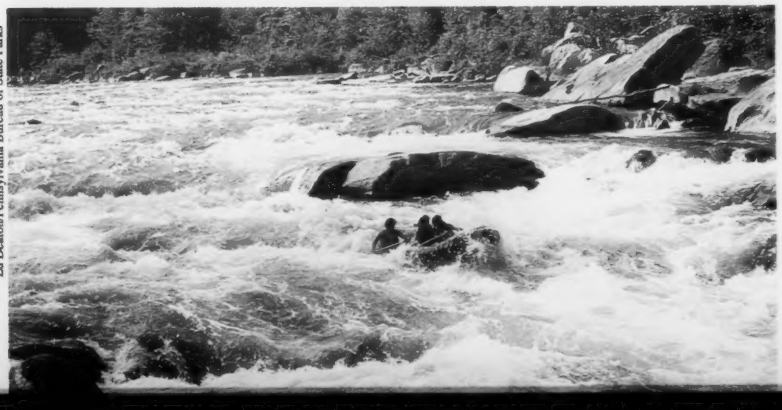
5. *Conflicts with other activities.*

Conflicts will occur with anglers, canoeists, campers, and with traffic on the roads near the river as rafting increases. These conflicts are probably most serious for anglers who seek isolation. Several rafting parties per hour will disturb the angler and the fish. Yet, considerable fishing occurs at the beginning of the fishing season, often before rafting starts. In addition, fishing most often occurs in early morning and evening hours, when rafters are not on the river.

Effects on canoeists are not well understood. Canoeists and rafters mutually occupy less violent segments of the river. Canoeists seeking isolation may be annoyed by large numbers of rafts, but large canoe parties are less likely to be disturbed.

Campers desiring a primitive environment could be interrupted by rafters, especially when they are on shore at launch, for take-out, or for a break. To minimize conflicts, put-in, take-out, and break spots should be located away from campsites.

To put these conflicts in perspective, consider a river with 25,000 rafters over a four-month season and an 80 percent weekend factor. About 550 rafters would be present every Saturday and Sunday, on average. With eight passengers per raft, four rafts per launch, and a launch every 15 minutes, 128 passengers could be handled every hour. A four-and-a-half hour launch period would be required from 8:00 a.m. to 12:30 p.m. Each lunch or break spot would serve about 140 people each weekend day if the passengers stayed there one hour and were replaced immediately upon leaving. A minimum of four lunch or break spots would be needed. While not a circus, this still presents a management problem in primitive or wilderness areas where adventure rafting takes place.



Ed Deaton/Pennsylvania Bureau of State Parks

Management Strategies

The principal management strategies applied to commercial white-water rafting in the northeast fall into six categories.

1. ***The adoption of a river recreation management plan.***
The only river to have such a plan is the West Branch of the Penobscot. The Maine Land Use Regulation Commission (LURC) accepted an easement of 500 feet on either side of the West Branch and adopted a recreation management plan in 1981 that essentially promotes a primitive environment type of recreation without encouraging substantial increases in recreation. It is unclear at this point, however, how LURC will address potential large increases in rafting activity.

2. ***The application of land use controls along the river.***
The Adirondack Park Agency regulates the land along the Hudson and Indian rivers. Portions of the rafted area are classified as wild, scenic, and recreational rivers and the park agency regulations define permitted and prohibited actions. Although these regulations are quite strict, they will not impinge upon rafting activities unless new roads or structures are needed to accommodate more rafters, something that is not likely to be a pressing problem since the rafting season is so short. Motor vehicle access is prohibited in the wild river portion of the raft trip, but the launch site and take-out site are outside this river segment. In Maine, the Land Use Regulation Commission also has general guidelines on land use in unorganized townships which affect the Kennebec. Here, too, these regulations do not seem to significantly affect rafting.

3. ***The imposition of use limits.***
As rivers become more congested, there is a tendency to impose limitations on daily use. The Youghiogheny is controlled by Ohiopyle State Park rules, which restrict commercial trips to four authorized concessionaires (who bid for the right to offer trips) and which limit the number of trips per day and the starting times for those trips. A rather regimented procedure is required to minimize congestion and still serve individual rafters plus over 60,000 commercially carried passengers per year. The West Virginia Department of Natural Resources has the authority to impose use limitations on rafting rivers but has not done so formally, since a detailed study of rafting is planned. The current informal "gentlemen's agreement" may constrain busy-day use on the New River, though. Finally, an outfitters' association has established limits for individual operators on the Kennebec, West Branch, and Indian-Hudson. Not all operators belong to the association, however, and the limits are generally above current weekend use.

4. ***The requirement to obtain access or other permits.***
Access to the West River in Vermont is through (but not on) state park land, and a special permit is needed by commercial outfitters. So far, only one outfitter has run this river, and water for rafting is sufficient only at spring and fall releases from a dam. Access to other rivers from private lands also requires the owners' permission and in at least one case, one outfitter charges others to take out on his property, the only readily available take-out site.

5. ***The certification of guides and imposition of safety requirements.***
Most, but not all, states require commercial outfitters to have trained guides and safe equipment. This is not likely to affect overall use, but it can reduce accidents in what is generally a dangerous sport.

6. ***The control of river flow.***
Rafting generally takes place on rivers where flow is regulated by one or more dams. These dams may enhance rafting by providing a regular flow of water all summer or may limit rafting by releasing water only occasionally. Dam operators have often been cooperative in releasing water for recreational purposes as long as releases are consistent with other objectives—power generation and flood control. There is some room for recreational management here, as it may sometimes be possible to divert traffic away from weekends by providing a bubble of water for a few hours on some weekdays.

Future use will depend upon how rapidly demand for rafting grows, both by first-time rafters and by repeaters.

John S. Tilney, Jr./Abt Associates

Conclusions

Rafting presents recreation and natural resource agencies with difficult choices. At one extreme is the maximization of recreational opportunities in a populous part of the country. This requires management of the logistics of rafting so as to provide as many adventure or float trips as can be safely accommodated given launch site characteristics and movement patterns on the river. At the other extreme is an emphasis on the scenic and ecological aspects of rafting so that crowding and noise do not intrude upon rafters and other recreationists and so that environmental damage to the shore is limited.

To make a defensible choice among management options which will stand up to vigorous objections, managers need a solid data base documenting points of congestion, environmental damage, conflicts with other recreation activities, and detraction from the aesthetic aspects of rafting by crowding. As recreation and conservation agencies undertake management studies, all of these data should be collected. This will require forecasting rafting demand, counting rafters on the river, noting the movement patterns of rafts on the river, observing ecological problems at lunch or break sites, and surveying rafters and other recreationists for their reactions to heavy rafting use.

Sentiment for use limitations will be weak among outfitters and local merchants who benefit from high volumes of rafting. It will take several years of relentless reference to and refinement of the facts of rafting before agreement on fair river use restrictions can be reached. Most parties to the issue do not see the whole picture and consequently they fight for their position, leaving little room for compromise in the first few years of deliberation over management strategies. It is only as the whole picture becomes accepted that a management plan can be successfully negotiated. □

To make a defensible choice among management options which will stand up to vigorous objections, managers need a solid data base documenting points of congestion, environmental damage, conflicts with other recreation activities, and detraction from the aesthetic aspects of rafting by crowding.

Acknowledgements: The authors wish to acknowledge the assistance of Captain Harry Shaver of the West Virginia Department of Natural Resources; the Pennsylvania Department of Natural Resources, Bureau of State Parks; Nancy Dvorin; and Judy Katz.

LAKE ST. CLAIR:
Since the MERCURY CRISIS

by John H. Hartig

If someone asked you to name the Great Lakes, you undoubtedly would not include Lake St. Clair, a heart-shaped bulge in the St. Clair and Detroit river system connecting the upper Great Lakes to the lower Great Lakes. What Lake St. Clair lacks in size compared to the other Great Lakes, it more than makes up for in recreational use. The area around Lake St. Clair is one of the most populated boating areas in the country, and approximately one-half of all sport fishing in Michigan (excluding salmon and lake trout) takes place there.

Lake St. Clair is unquestionably the recreational heartland of the Great Lakes basin. Its reputation, however, is not without tarnish.

In 1969, the Ontario Water Resources Commission (the predecessor of the Ontario Ministry of the Environment) reported elevated levels of mercury in sediments of the St. Clair River. Another sediment survey later that year provided confirmation, with mercury concentrations over 1000 parts per million below one industrial outfall. The industry responsible for this contamination was the Dow Chemical Chlor-Alkali Plant in Sarnia, Ontario. Since 1949, Dow Chemical had been operating a mercury cell plant in Sarnia (a second plant came on line in 1965) for production of chlorine and caustic soda. From their production process, mercury was being lost to the St. Clair River.

What transpired became known as the "mercury crisis."

Mercury had contaminated both the sediments and the fishery of the St. Clair River, Lake St. Clair, and the Detroit River. Most of the mercury had settled in Lake St. Clair. The lake's commercial fishery, which landed over .9 million pounds per year during the 1960's had to be closed down and all sport fishing restricted. The St. Clair commercial fisheries were substantial, providing about 40 small family companies with between $1 million and $2 million worth of fish per year. The fishing operations were extensive, with fleets of boats, modern nets and equipment, and an associated bait and equipment supply industry. The closing of the fisheries had a devastating financial effect on the industry, and the provincial and Federal governments offered a series of loans to the fishermen to help them survive while the ban was in effect.

Mr. Hartig is an environmental scientist with the Michigan Department of Natural Resources, Lansing 48909.

HEALTH WARNING

The following species of fish in the waters described below have been found to contain potentially dangerous levels of mercury and can cause serious illness if eaten regularly over a long period of time.

LAKE ST. CLAIR, DETROIT RIVER, ST. CLAIR RIVER: Walleye, Perch, Muskellunge, Rock Bass, Smallmouth Bass, Catfish, White Bass & Sheepshead (Drum).

LAKE ERIE, AND LAKE HURON south of a line extending east from Port Sanilac: Walleye, White Bass, Sheepshead (Drum).

Children and pregnant women are especially advised to avoid eating any of these fish!

MICHIGAN DEPARTMENT OF PUBLIC HEALTH

To understand the public concern over the mercury crisis one must keep in mind the social climate of that time. It was 1970, and public outcry against pollution was at its zenith. There were reports that Lake Erie had died; public bathing beaches were closed to swimming. Pollution had to be stopped, and the mercury crisis became a focal point.

In March of 1970, the Ontario Water Resources Commission directed Dow Canada to install treatment facilities to eliminate mercury discharges to the St. Clair River, and they complied rapidly. Later, Dow Canada voluntarily shut down its two mercury cell plants in Sarnia and one in Thunder Bay, Ontario. Interestingly enough, at no time was Dow Canada in violation of any government mercury discharge standard.

As a direct result of the mercury crisis, another mercury cell plant which discharged to the Detroit River from Wyandotte, Michigan, was shut down in 1972. At the time of its shutdown, this plant was owned by BASF Wyandotte Corporation.

Mercury is a naturally occurring metal, familiar to most people through the use of thermometers. It is used in some industrial processes such as Dow Canada's production of chlorine and caustic soda and in the manufacture of some types of electrical apparatus. At one time, mercury was widely used as an antifouling agent in paints and as a controller of fungal diseases of seeds, flower bulbs, and other vegetation. It is still used as an antimicrobial agent.

Mercury is also toxic. It is found in the environment in different chemical and physical forms, the most toxic being methylmercury. In its elemental form, mercury is not regarded as a serious contaminant in water because it is almost completely insoluble in water. However, elemental mercury in sediments can be transformed by microorganisms into a form which is much more water soluble, biologically mobile, and toxic than other forms. Certain fishes have been found to accumulate mercury in their tissues at concentrations 5000 to 50,000 times greater than in surrounding waters.

John H. Hartig

Much of our knowledge of the effects of mercury on the human body comes from an incident of mercury poisoning in Minimata, Japan. In 1953, a few people living in the vicinity of Minimata Bay became ill with a strange series of disorders: convulsions, tunnel vision, blindness, madness, and excruciating pain. Some died. Shortly thereafter, doctors discovered that the victims were being poisoned by mercury in the fish they ate from the bay, which was being polluted by a chemical company. By 1976, 120 Minimata residents had died of mercury poisoning and 800 had mercury-caused brain damage. By 1978, 8100 residents claimed health damage and about 1500 of them had been examined and certified as cases of mercury poisoning. Today in Minimata, fetally damaged children and other victims continue to seek relief from pain years after they have stopped eating contaminated fish.

No human illness has been linked to consuming mercury-contaminated fish from Lake St. Clair. The concentrations of mercury in Lake St. Clair fish were less than those in Minimata Bay, and the North American diet is much lower in fish than is the Japanese diet. Scientists are still concerned, however, over the effects of long term, low level exposure to mercury.

Because approximately .2 million pounds of mercury were discharged to the St. Clair River from the Dow Canada Chlor-Alkali Plant in Sarnia, Ontario and Michigan set up monitoring programs to determine the degree of mercury contamination in the fishery and the effect of cessation of the mercury discharge, and to predict if and when the mercury concentration in fish would fall to safe levels. Preliminary predictions by researchers were that it would take a century to decontaminate a mercury-polluted ecosystem.

Bob Haas

Approximately one-half of all sport fishing effort in Michigan (excluding salmon and lake trout) is expended on Lake St. Clair.

John H. Hartig

Today, results from these monitoring programs have shown a significant decrease of mercury in all species of fish. In general, the concentration of mercury in fish from Lake St. Clair is less than one-third what it was in 1970. The decline of mercury in Lake St. Clair walleye is particularly significant because walleye are the most sought after sport fish in Lake St. Clair.

As a result of the decline of mercury in Lake St. Clair fishes, the Michigan Department of Public Health has dropped walleye, largemouth bass, smallmouth bass, sheepshead, and white bass from Lake St. Clair's public health advisory. Today, only muskellunge are advised to be consumed no more than one meal per week because of elevated levels of mercury. Children and women who are pregnant, nursing, or expect to bear children are advised against eating certain sizes of certain fishes, and the commercial fishery remains closed for some fishes as of 1982.

Research scientists have attributed the decline of mercury in Lake St. Clair fishes to the cessation of discharge of mercury on the St. Clair River and to the translocation of mercury-contaminated sediments from Lake St. Clair to Lake Erie. After May 1970, mercury discharges to the St. Clair

PUBLIC HEALTH ADVISORY

Some sport fish contain chemical contaminants. Although levels of some contaminants have markedly declined, uncertainties about the impact of prolonged exposure dictates the following advice:

Do not eat any fish—Deer Lake (Marquette Co., Ishpeming Twp.), Tittabawassee River, Saginaw River, Pine River (downstream from St. Louis), Chippewa River, (downstream from Chippewa Road), Raisin River (downstream from Monroe Dam), Kalamazoo River (downstream from Kalamazoo). Portage Creek (downstream from Milham Park) and Shiawassee River (M-59 to Owosso).

Do not eat certain fish—Cass River (downstream from Bridgeport) avoid catfish, Grand River (Clinton Co.) avoid carp, Lake Macatawa avoid carp, Hersey River (Reed City area) avoid bullheads and trout, St. Joseph River (downstream from Berrien Springs Dam) avoid carp.

Certain Great Lakes fish should not be eaten—by children, women who are pregnant, nursing or expect to bear children. **Limit consumption** by all others to no more than 1 meal per week. Lake Michigan—carp, catfish, salmon[3], trout[3] and whitefish;[1] Lake Superior—lake trout; Lake Huron—carp,[2] catfish,[2] muskellunge,[1] salmon,[1,3] trout,[1,3] Lake St. Clair and the Detroit and St. Clair rivers—muskellunge; and Lake Erie (western edge)—carp, catfish and muskellunge.

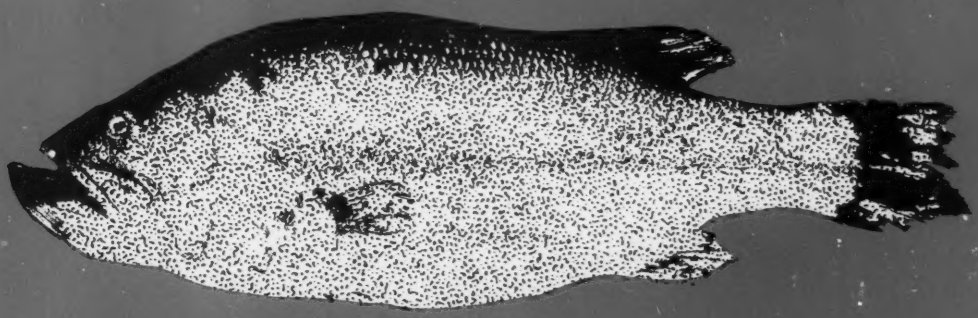
[1] Southern half of lake only.
[2] Saginaw Bay area only.
[3] Advisory also applies to tributaries into which these species migrate.

NOTE: Fatty fish continue to show higher contaminant levels than lean fish. Cleaning fish by skinning, filleting, and trimming off fatty portions, reduces contaminant levels. Baking on a rack, barbecueing, poaching or frying in vegetable oil also reduce contaminant levels.

The health advisory pictured on the left was issued by the Michigan Department of Public Health in 1970. Today, only muskellunge remain on the public health advisory for Lake St. Clair.

John H. Hartig

The area around Lake St. Clair is one of the most populated boating areas in North America.



Largemouth bass have been removed from Michigan's public health advisory for Lake St. Clair.

River were negligible. Dow Canada now uses a chlor-alkali process based on a diaphragm cell, which uses no mercury. Today, all industries in Ontario are required to maintain a zero discharge limit for mercury, and Michigan maintains a 0.05 microgram per liter effluent mercury standard for all point sources.

Resuspension and onward transportation of mercury-contaminated sediments from Lake St.Clair to Lake Erie has resulted in a 64 percent decrease in sediment mercury in Lake St. Clair from 1970 to 1974. No major effect in Lake Erie has been found as a result of continued loading of mercury-contaminated sediments from Lake St. Clair via the Detroit River. In fact, as a result of the decline of mercury contamination, the Michigan Department of Public Health has dropped walleye, sheepshead, and white bass from the public health advisory on Lake Erie. Today, only muskellunge, carp, and catfish are advised to be consumed no more than one meal per week. In addition, a 1980 survey by the Michigan Department of Natural Resources found mercury levels in coho salmon from Lake Michigan and Huron. The dilution factor in Lake Erie may have been adequate to prevent large-scale uptake of mercury by fishes, or mercury contaminated sediments are being bound and covered up by new sediments.

Bob Haas

Dividends from a recent muskellunge fishing contest in Lake St. Clair. A public health advisory remains in effect on muskellunge.

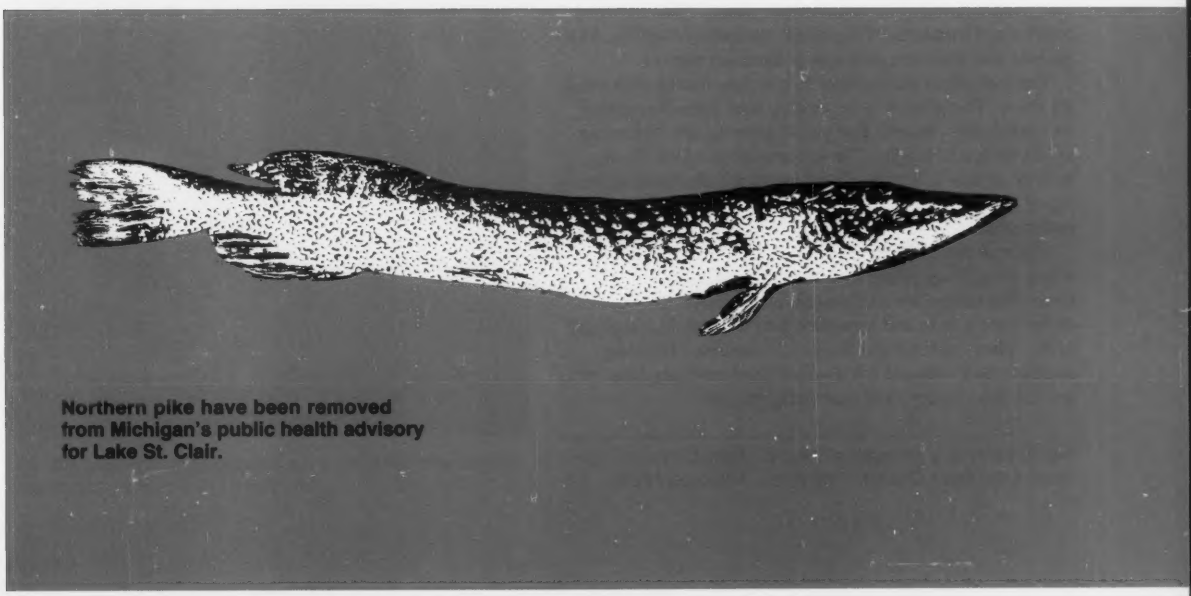
John H. Hartig

The St. Clair River, with Sarnia's (Ontario) petrochemical industry in the background.

The decline of mercury in Lake St. Clair fishes is particularly remarkable considering that as recently as 10 years ago researchers thought it would take at least a century for such improvements to occur. But this is not the real lesson to be learned from the mercury crisis. The real lesson is that industrial and municipal discharge permits have to be written tight enough so that low-level discharges or accidental losses of pollutants (e.g. polychlorinated biphenyls, dioxin) will not occur over extended periods of time and result in environmental crisis. Recall that the Dow Canada Chlor-Alkali Plant in Sarnia was never in violation of a government mercury discharge standard. Yet, approximately .2 million pounds of mercury were lost to the St. Clair River, resulting in the desistance of commercial fishing and limitation of sport fishing.

We must have the foresight to know if and when discharges of pollutants will have adverse cumulative or synergistic effects on the environment. □

EDITOR'S NOTE: "Mercury Pollution Perspective," in the fall 1978 issue of Water Spectrum *(Vol. 10, No 4), discussed several instances of mercury contamination. The present article looks at the progress made to date in one of those instances --Lake St. Clair.*



Northern pike have been removed from Michigan's public health advisory for Lake St. Clair.

Saving an ORCHID

Jim Ettman

by Laura E. Brantley

In Conway County near Plumerville, Arkansas, the U.S. Army Corps of Engineers is constructing a water supply reservoir for the city of Conway. The reservoir will be formed by impoundment of Cypress Creek. Cypress Creek is a tributary to the Cadron Creek which eventually runs into the Arkansas River. The reservoir will replace the existing municipal water supply for the city of Conway.

During the development of a vegetative clearing and reservoir filling plan, orchids were found. Unlike the spring prom corsages, these tiny orchids are very inconspicuous. The blossoms are yellow-green to green in color, blending with the surrounding herbaceous plants of the wet wood. The flower is commonly called the green wood orchid.

The technical name of the plant is *Platanthera sp.* (formerly *Habenaria sp.*). As is characteristic of the Orchidaceae family, this small flower has three sepals, three petals—one petal distinctly larger than the others, one spur, and a fused sytle stigma and stamens. The ovary is inferior and hundreds of tiny seeds are matured within. Mosquitoes and wind are probable pollination vectors.

The individual plants have two to five leaves with parallel veins. The plant in a vegetative state (non-flowering) has one ot two leaves. The plants grow to approximately 16-24 inches in height. The inflorescence of the flower is 6-12 inches in length. The flowers are clustered at the top of the stem. Each flower has a long bract which curls underneath. The fragrance of the flower is slightly sweet.

The root structure of the plant is significant, especially when identifying plants in a vegetative state or wintering state. The tuber-like root system is extensive. It is thick at the stem's base and separates into three to five separate roots. These extend and thicken, sometimes forming another tuber from which another plant emerges. The roots are shallow, fleshy, and extremely fragile.

Ms. Brantley is a biologist in the U.S. Army Corps of Engineers Little Rock District, Little Rock, Arkansas 72203.

The discovery of *Planthera sp.* occurred during a vegetative study conducted by contract. Corps of Engineers biologists investigated the area and found additional colonies of orchids. The orchids were located within the proposed reservoir, so destruction of the plant colonies was inevitable. Although the orchid is not on the Federal list of endangered plant species, the State of Arkansas identified the plant as one of special concern and significance. Removal was the only alternative to enhance chances for survival.

U.S. Army Corps of Engineers project lands nearby did not have suitable habitat for the orchids. State parks were investigated, and two near the project area were identified as relocation sites—Petit Jean State Park and Pinnacle State Park. Petit Jean State Park is atop Pitit Jean Mountain in southwestern Conway County, while Pinnacle State Park is in northwestern Pulaski County.

The orchids needed a habitat similar to the wet wood from which they would be removed. The species also required a slightly acidic soil (pH 6.1) and a partially opened canopy. The orchids exist in the soil with mycorrihizae (fungi) which attach to the roots of the plants. This symbiotic association enables the orchid to survive. During removal, enough soil would have to be moved to insure transferral of the fungi and to lessen the degree of mechanical damages. State park personnel searched for areas within the parks for indicator species. Indicator species are other plants which occur in conjunction with a particular plant species. One particular indicator plant for *Plantanthera sp.* is the royal fern *(osmunda regalis, L.).*

U.S. Army Corps of Engineers personnel identify colony boundaries. Author is in foreground.

Max Wilkind

At this stage of growth, before flowering, the plants are about twelve inches in height.

Jim Ettman

Flowering *Plantanthera sp.*

The presence of moisture in the soil was necessary for an easier and safer transplant, so spring was suggested as the best time for removal procedures. In early March 1981, the plants were approximately two to three inches in height and were partially submerged in water seeping from a knoll nearby. Jim Ettman, park naturalist at Petit Jean State Park, led the transplanting team. Petit Jean State Park manager Randy Johnson and his people, along with personnel from Pinnacle State Park, aided the Corps in the removal procedure.

Using hands and spades, our group removed approximately 2000 plants from the project area. We placed one-foot by one-foot squares containing approximately 25 plants each in medium-size plastic bags and used twist ties to seal the bags to prevent moisture loss. Transplanting in the parks needed to be done within two days. Mechanical mortalities were expected to affect peripheral plants. All park personnel planted their orchids in acceptable habitat throughout their park areas. The plants survived in goodly numbers and continued to grow after two years of flowering following the transplant. In May 1981, most of the plants emerged and flowered in spite a very dry summer in 1980. In March 1982, an abundance of orchids appeared.

In our monitoring plan, we periodically surveyed the project area for any new species which could emerge or flower. Some orchid species bloom only every two years, others less frequently. Park personnel checked their retransplanting areas for any new species which could have been inadvertently transplanted. To date, no additional members of the Orchidaceae family have been noted.

There are approximately 17 species of the Plantanthera genus in this region of the country. Many of these species occur in Arkansas, Missouri, and neighboring states. Since most of these are rather inconspicuous and isolated, they are overlooked by the general public. Although complete vegetative studies do not exist for each county, only a few report the natural occurrence of *Plantanthera sp*. The successful transplant of this species in Pulaski and Conway counties extended the known geographical range of the plant in Arkansas and made it available for the general public to view and enjoy.

Herbarium samples were made and are stored at the Little Rock District Corps of Engineers office. Specimens were also sent to the Maria Selby Botanical Gardens in Sarasota, Florida. The Arkansas Natural and Cultural Heritage Commission gave advice concerning placement of the orchids. □

Jim Etman

Distinguishing orchids from other plants on the wet wood floor.

Orchids with only one to two leaves during their vegetative state.

Max Wilkind

Finding Salmon & Trout in Lake Ontario

by James M. Haynes

Where do you catch salmon and trout in a 7500 square mile lake with an average depth of 280 feet and a bottom structure resembling a soup bowl? Millions of juvenile salmon and trout are stocked annually in Lake Ontario, yet anglers frequently ask this question. With funding and support from the New York Sea Grant Institute, the Research Foundation of the State University of New York (SUNY), and local anglers' groups, faculty and student researchers at the SUNY Colleges at Brockport and Fredonia are studying the movements, distribution, and habitat preferences of salmon and trout in Lake Ontario. By attaching radiotransmitters to fish and setting nets as far as 15 miles out into the lake, researchers are providing answers to both anglers' and scientists' questions about the ecology of salmon and trout stocked in Lake Ontario.

Beginning the the mid-1960s, the reintroduction of lake trout and the introduction of brown trout, steelhead/rainbow trout, and Pacific salmon (coho and chinook) to the Great Lakes have sparked remarkable interest and enthusiasm among anglers, recreational businesses, and fisheries biologists throughout the region. Major salmon and trout stocking efforts by Great Lakes states and provinces and U.S. and Canadian federal agencies are designed to establish a quality recreational fishery and to restore ecosystem balance in the lakes. Native lake trout were once abundant in all the Great

Photos by the author

Dr. Haynes is an assistant professor of biology at the State University of New York at Brockport, 14420.

Lakes, so a major fishery management goal is to re-establish self-sustaining stocks of lake trout. Other salmon and trout are stocked in an attempt to control, by predation, large invader populations of alewifes and rainbow smelt. New York alone is stocking five million salmon and trout annually, a number representative of other states and provinces.

The history of Great Lakes fisheries is a sad chapter in the history of man's exploitation and destruction of economically important natural populations and their environmental resource bases. As the Great Lakes region was settled in the early 1800s, commercial fisheries for Atlantic salmon (Lake Ontario only), lake trout, whitefish, lake herring, various ciscoes, walleye, and other fishes prized as high-quality food became profitable and grew. As fishery operations expanded and harvests increased, these highly sought-after species began to decline. Following the classic pattern of resource exploitation, instead of reducing fishing effort to ease pressure on commercially valuable fish stocks, effort was increased to maintain high harvest levels. In consequence, selected species populations in certain Great Lakes collapsed. The lake sturgeon was generally first. Because it damaged netting gear, deliberate attempts to eradicate it were made in all Great Lakes and were successful first in Lake Ontario by 1900.

At the same time over-exploitation was occurring, settlers in the Great Lakes region were building cities and industries and were substantially altering land and water resources. Vast hardwood forests that limited erosion, provided regular stream flows, and maintained cool temperatures in Great Lakes tributaries were cut down, and dams were built on streams to power mills. In Lake Ontario, because deforestation and damming prevented successful reproduction in tributaries, what may have been the largest Atlantic salmon population in the world was nearly extinct by 1870. Other species, notable warm-water fishes such as the walleye, were also greatly affected by development along Great Lakes bays and tributaries.

In the 1820s, the Erie Canal provided a commercial link from Lakes Erie and Ontario to the Hudson River and Atlantic Ocean. That link also permitted exotic species such as the alewife and possibly lamprey to reach Lake Ontario from the ocean. Alewifes are voracious zooplankton (microscopic aquatic animals) feeders, and they quickly began competing with plankton-feeding native whitefish, ciscoes, and shiners (important food fish for some commercially valuable species). In the 1930s the Welland Canal connected Lake Erie to Lake Ontario. Within a decade lampreys and alewifes had invaded the upper Great Lakes, and rainbow smelt, first introduced in Lake Michigan in the 1920s, spread to Lake Ontario. At the same time, human population and industrial growth throughout the region added ever-increasing amounts of raw sewage, chemicals, and industrial waste to lake waters.

Thus, Great Lakes fish populations were exposed to a disastrous array of pressures arising from man's use of the environment. In the 1920s, lake herring populations collapsed in Lake Erie and whitefish populations collapsed in Lake Huron. As fishing pressure increased, diminished fish stocks became more vulnerable to lamprey predation, and as commercial stocks collapsed in the various Great Lakes, both commercial fishermen and lampreys switched to the the next available fishery stock with individual fish of largest size. Lake trout, burbot, whitefish, lake herring, and various ciscoes declined and collapsed, especially in the lower Great Lakes. At the same time, alewifes and smelt successfully displaced native forage fish stocks (primarily emerald and spottail shiners and deepwater sculpins, the latter also pollution related), or, in the case of smelt, may have preyed on young-of-the-year lake trout. In the absence of native predators, alewife and smelt populations exploded throughout the Great Lakes. By the 1950s, commercial harvests consisted primarily of carp, drum, bullhead, and perch. Lake Erie was considered dying, and lake ecosystems, except for Lake Superior, were seriously out of balance. Despite the near absence of commercial fishing, lampreys and pollution prevented a resurgence of native predators while overabundant, unexploited alewifes and smelt formed windrows on Great Lakes beaches during their periodic die-offs.

Through the International Joint Commission for the Great Lakes, the U.S. and Canadian governments agreed to restore Great Lakes water quality by mandating municipal and industrial pollution control. Under these conditions, the Great Lakes Fishery Commission decided upon a two-pronged approach to restore health to Great Lakes fisheries: introduction of salmon and trout by stocking and lamprey control. Only recreational harvesting of salmon and trout is permitted in U.S. waters; Canada allows some commercial fishing for salmon and trout. However, it was not until substantial lamprey control was achieved by chemically treating lamprey spawning streams that salmon and trout populations in the Great Lakes grew large and vigorous. That increase generated great interest as fishermen crowded nearshore and tributary areas of the Great Lakes to catch the biggest fish they had ever seen.

Initially, anglers concentrated on spawning-run fish in tributaries: salmon in autumn, steelhead/rainbow trout in spring. As brown and lake trout numbers increased, fishermen learned their locations in nearshore lake areas and began to understand their habitat preferences. On Lake Ontario, both anglers and scientists became very interested in the location, distribution, and habitat preferences of stocked salmon and trout.

A large lake can be a very perplexing place for fishermen. Anglers know that fish often prefer to be near "structure," often associating with rocks or debris on bottom or with brush along shore, but Lake Ontario offers little such physical structure. The total area of the lake is immense compared to shoreline area, while wave action and nearshore currents scour beach and bottom zones, so little structure is available for fish. Furthermore, nearshore and surface water temperatures in Lake Ontario are above salmon and trout tolerance limits from late June through early September.

With minimal help from scientists, anglers learned the nearshore seasonal locations of Lake Ontario salmon and trout species by trial-and-error observation. In spring (ice-out to May-June), brown, lake, and steelhead/rainbow trout are found in cold water (36-50°F) very close to shore (often in two to three feet of water). In autumn (mid-September to early November), coho and chinook salmon ascend streams to spawn, brown trout are again very close to shore, and lake and steelhead/rainbow trout are in somewhat deeper water.

Obvious gaps in knowledge concerning the whereabouts of some species in certain seasons became evident. Aware of these gaps, anglers pressed scientists to study salmon and trout ecology in Lake Ontario. In particular, anglers desired knowledge about chinook salmon, the largest, most glamorous species stocked in the Great Lakes. Their accessibility to anglers on Lake Michigan in summer has helped establish an important, economically beneficial recreational fishery there. Anglers and recreational businesses wanted to see a similar fishery develop on Lake Ontario. As a result of these factors, the SUNY research group began studies to determine the seasonal locations and habitat preferences of salmon and trout in Lake Ontario. To do this we used two methods rarely used in Great Lakes fishery studies: radiotelemetry and vertical gill netting. We have documented seasonal movements of brown and steelhead/rainbow trout and Pacific salmon using telemetry. Vertical gill nets provide a method to determine precise depth and temperature preferences of salmon and trout in summer.

Methods

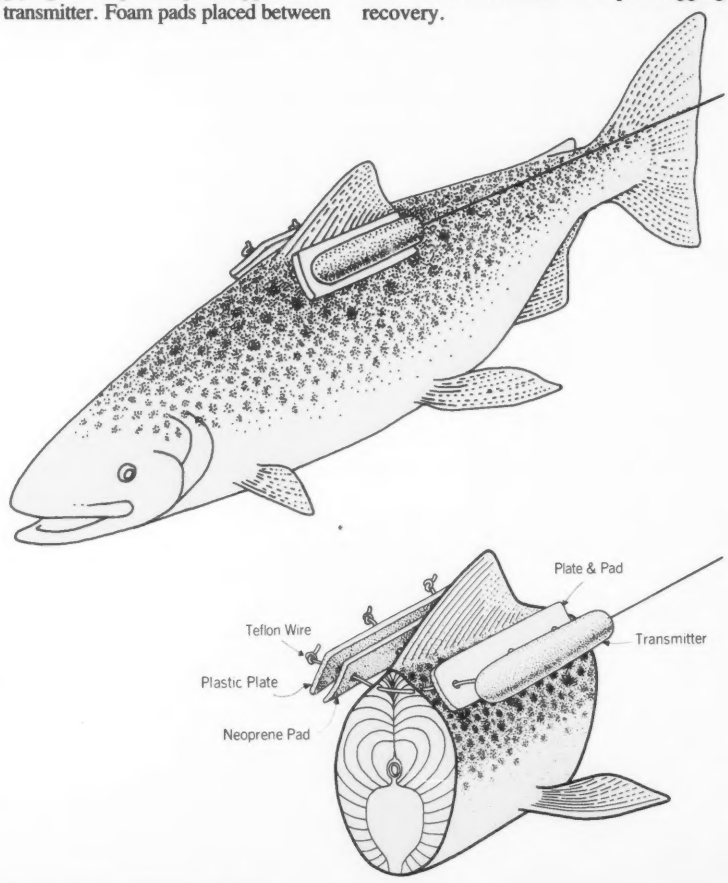
Radiotelemetry has been used to study nearshore movements and stream selection by spawning-run salmon and trout in the Great Lakes, most notably with steelhead/rainbow trout in Lake Superior (University of Minnesota), coho salmon in Lake Michigan (University of Wisconsin), and coho and steelhead/rainbow in Lake Erie (SUNY Fredonia). In Lake Ontario we are examining salmon and trout movements in spawning and nonspawning seasons.

Radio receivers and transmitters were designed by the Bioelectronics Laboratory at the University of Minnesota and operate at 53 MHz. Transmitters (often temperature sensing) are separately identifiable, and up to 100 can be distinguished simultaneously by receivers. Typically, 10 to 30 fish are tracked per season. Transmitter size depends upon battery size (larger batteries give longer life). Most transmitters are ¾ by 3-inch cylinders encased in epoxy, weigh about one ounce in water, and have an operational life of four to six months.

Salmon and trout are captured for radiotagging during periods when they move close to shore (spring and fall) using two methods: electroshocking or beach seining. A pontoon boat mounted with a generator and shocking booms creates an electrical field in the water. By moving slowly along shore in Lake Ontario or tributaries, salmon and trout are attracted into the field, stunned, netted, and placed in an aerated tank on board. A 650-foot beach seine (borrowed from the New York State Department of Environmental Conservation) is used to enclose pockets of water along the shore of Lake Ontario, thus trapping fish and permitting their capture.

Fish are tagged on site or kept for a period in holding cages to assure healthy condition. Before tagging, they are placed in an anesthetic solution to render them unconscious. Two methods are used to place transmitters on or in fish: external attachments near the dorsal fin and surgical implantation inside the body cavity. External transmitters have three wires embedded in their epoxy coating. A sharp needle is used to thread wires under the dorsal fin but above the major swimming muscles. Attachment wires are tied snugly against a plastic plate opposite the transmitter. Foam pads placed between transmitter/plastic plate and fish minimize tissue abrasion. A stiff antenna wire projects posteriorly from external transmitters. This technique is quick (about three minutes) and involves minimal trauma, but there is a risk that the fish will tear off the transmitters, especially while moving to spawn in streams.

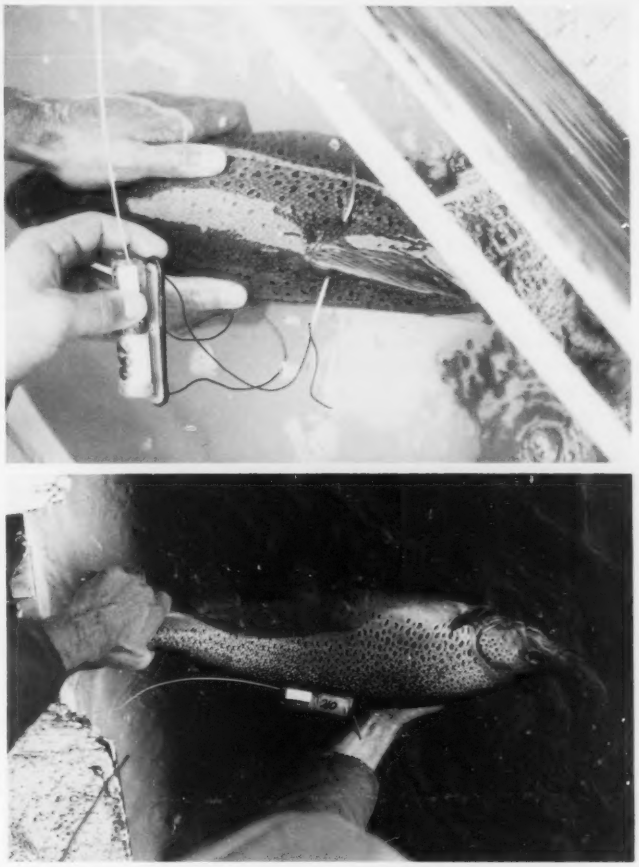
Radiotransmitters are surgically implanted by incision in the belly area. Flexible antennae are inserted parallel to the main body axis, followed by the transmitter, and sutures close the incision. This technique requires more time (about eight minutes) and risk greater trauma but eliminate risk of losing transmitters. In fact, post-operative and subsequent field mortality is substantially higher among surgically tagged salmon and trout. In all tagging operations, fish gills are irrigated and antiseptic is applied to all attachment and insertion points to retard infection. Most surgically tagged and some externally tagged fish are held 12 to 24 hours to assure full post-tagging recovery.



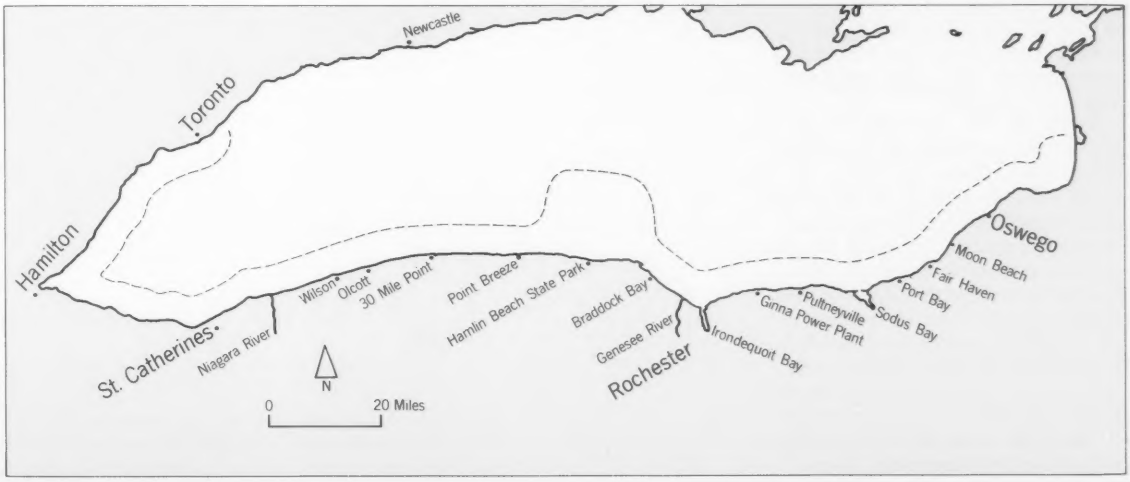
External radiotransmitter attachment.

After release, tagged salmon are tracked by truck, boat, or airplane, depending upon circumstances. When fish are within a mile of shore between Point Breeze and Irondequoit Bay, a truck mounted with Yagi antenna tracks them at half-mile intervals along shore. If fish are farther offshore in the same area or if we want to pinpoint their locations to obtain precise depth information, we track from boats mounted with Yagi antennae. When fish move out of the local study area, we use an airplane fitted with small loop antennae; special, programmable scanning receiver tracks fish from the rapidly moving plane.

Vertical gill nets are rarely used in fishery studies because of the difficulty in setting and holding them in place over deep water. Their only previous use for salmon and trout in the Great Lakes occurred in Lake Erie at a maximum depth of 150 feet. In Lake Ontario we set vertical nets over depths ranging from 25 to 600 feet. Floating bars suspend nets (up to 150 feet long, from the water surface, while spreader bars at 25-foot intervals maintain standard 16-foot width. Net mesh sizes used are suitable for smelt, alewifes, salmon, and trout. Each time nets are set and retrieved, a temperature profile of the water column is taken at 6.5 foot intervals from surface to bottom. By comparing the depth at which fish are caught in a net with daily temperature profiles, the preferred temperatures of fish are determined.



Partially completed external attachment and completed external attachment.



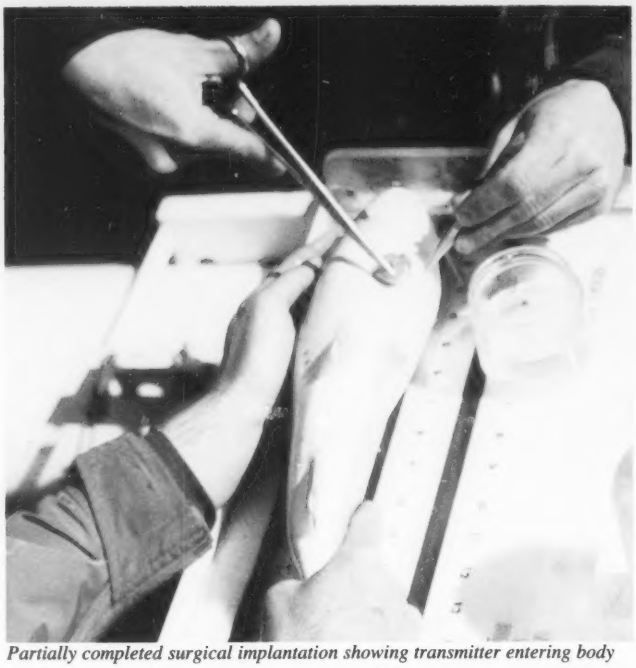
Lake Ontario salmon and trout study area.

Results

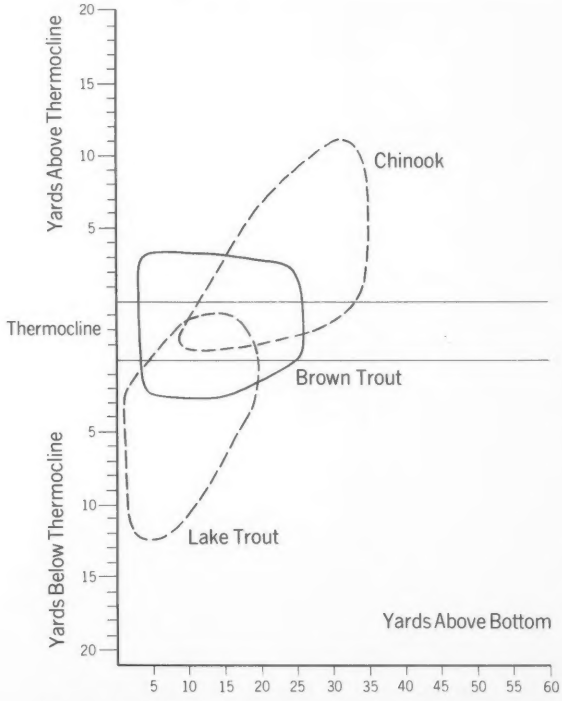
Several key questions about salmon and trout ecology in Lake Ontario are addressed in our study: 1) Where are chinook and coho salmon located in spring and summer? 2) Where are steelhead/rainbow trout located in summer and autumn? 3) What movements do lake and brown trout exhibit in their nearshore habitats? and 4) What are the seasonal movements and precise habitat preferences of all salmon and trout species in Lake Ontario? Our attempts to answer these questions were both rewarded and thwarted, depending upon the habits of each species.

Our research began by studying brown trout movement, behavior, and spawning stream selection in autumn 1980. Brown trout first appear near shore in autumn as water temperatures drop below 65°F. To our considerable surprise, brown trout, supposedly the most sedentary of the species stocked in Lake Ontario, moved as far as 70 miles in very shallow, nearshore waters while in spawning condition. Although several tagged fish seemed attracted to Sandy Creek (the tributary where most of our capture and tagging activities take place), no brown trout ascended the creek farther than one mile, despite the presence of suitable spawning areas farther upstream. No tagged brown trout were tracked entering other tributaries, indicating little reproductive success. While most tagged brown trout were stocked a few miles to the west two years before our study, one was stocked 50 miles to the east, confirming the extensive movement capabilities of brown trout in Lake Ontario. As nearshore and surface water temperatures drop below 39°F with the onset of winter, tagged brown trout move offshore to deeper, warmer 39°F water, where radio signals are reduced.

In spring 1981 we tagged more brown trout, several of which exhibited movements similar to those observed in fall 1980. However, most fish moved considerably farther east toward cooler water as summer approached. Brown trout continue to roam close to shore, investigating stream mouths and power plant outflows, until water temperatures exceed 65°F in June or July; then they begin moving offshore to deeper, cooler water where, again, radio signals are completely attenuated (at depths greater than 40 feet). One spring, brown trout tagged with a long-lived transmitter returned nearshore in autumn to their original area of preference, nicely confirming our



Partially completed surgical implantation showing transmitter entering body cavity.



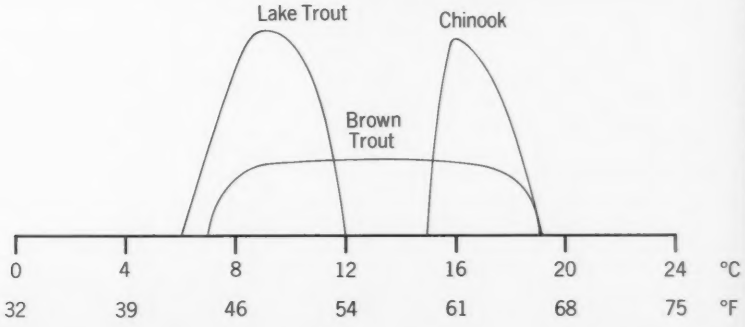
Relationship of lake and brown trout and chinook salmon to the thermocline and the bottom in summer. The vertical axis displays species position relative to the thermocline regardless of absolute thermocline depth and temperature. The horizontal axis displays the overall species distance from bottom.

hypotheses of nearshore and offshore movements based upon temperature preferences.

Once brown trout moved offshore in early summer, vertical gill netting found them associated with a wide range of temperatures. Most interesting is the strong degree of association brown trout exhibit with the thermocline, or zone of rapidly changing temperature in the water column. Intense summer sun heats the surface water of a lake but sunlight penetrates only to limited depths as solar energy is absorbed. The thermocline begins where the sun's energy has mostly been absorbed by surface waters, and a rather sharp decrease in water temperature (two degrees or more per yard) is observed with increasing depth. Thus, in summer, a lake is typically stratified with warm, less dense surface waters lying on cool, moderately dense thermocline waters that lie on the permanently cold, densest (39°F) bottom waters.

In Lake Ontario temperature stratification typically begins in late June and ends in September. Because the warmest layers of the water are near the surface and directly onshore, salmon and trout move offshore in summer to deeper waters and cooler, preferred temperatures. In Lake Ontario the thermocline is a dynamic zone that provides the only real physical structure for fish. As summer progresses the thermocline is driven deeper into the water column, although wind velocity and direction play a daily role in determining thermocline depth. In 1981-82 the average depth and temperature of the thermocline ranged from 10-98 feet and 46-65°F, respectively, and its width averaged 13 feet.

Boat with radiotracking antenna.



Summer temperature preferences of lake and brown trout and chinook salmon.

Vertical gill net with chinook salmon coming on board.

Brown trout association with the thermocline is strong, despite great variations in depth and temperature of that zone. Over 75 percent of brown trout were netted in or within 10 feet of the thermocline in summer 1981, a finding repeated in 1982. About 30 percent of brown trout were netted within 10 feet of the lake bottom, but 80 percent of those were caught there when the thermocline intersected the bottom. Brown trout are not found farther than three miles (usually in less than 100 feet of water) offshore in any season and prefer to be as close to shore as possible given suitable water temperatures. Mean preferred water temperature, as defined by temperature sensing radio transmitters in spring and fall and by netting in summer, is 55°F for brown trout.

Steelhead/rainbow trout were radiotracked in spring 1981 and spring and fall 1982 and exhibited even greater movement than brown trout. Steelhead/rainbow were tagged as they ascended and descended spawning streams. Several successfully spawned, then returned to Lake Ontario and engaged in extensive movements along shore before moving to the open lake. An extraordinarily cold winter of 1981-82 delayed lake warming by four to six weeks compared to normal years. In 1981 nearshore lake temperatures reached 50°F by mid-May, and our tagged steelhead dispersed far out into Lake Ontario. In 1982 nearshore lake temperatures did not reach 50°F until mid-June, when steelhead again dispersed into the open lake.

In 1982 we confirmed the suspected importance of the "thermal bar" relative to the dispersal of steelhead/rainbow far out into Lake Ontario. The thermal bar is a zone of rapid horizontal temperature change extending toward shore at an angle from lake surface to bottom. As the lake begins to heat in spring, nearshore waters warm first. If water temperatures are measured at intervals while moving offshore, at some point over a distance of 200 feet or so surface temperature will drop markedly, typically from 45 to 39°F early in spring and 54 to 45°F farther offshore later in the spring. The thermal bar and other sharp horizontal temperature gradients act as a barrier that seems to pen steelhead/rainbow nearshore after they leave spawning streams. As nearshore surface temperatures approach 50°F and the thermal bar is "pushed" farther offshore (five to 20 miles), the steelhead/rainbow literally spill out into the open lake. Several steelhead bore temperature sensing transmitters that confirmed their presence in the thermal bar or other temperature gradient regions and the importance of the 50°F transition temperature. Two steelhead tagged in spring 1982 were later caught in Canadian waters many miles from their last known locations.

Steelhead/rainbow trout are notoriously net wary, and few have been caught in our vertical nets. However, acting on our research findings, in 1982 anglers sought out the thermal bar and caught steelhead near it. In summer they have fished five to 10 miles offshore, observed many large fish with depth sounders in 50-65°F water near the surface, and caught occasional steelhead/rainbow trout. Thus, it appears that steelhead behave in Lake Ontario just as they do in their native north Pacific Ocean waters. They are dispersing, open-water wanderers that do ot concentrate in special open-lake or nearshore areas in summer. Consequently, they are difficult to find, and anglers must fish considerable distances offshore with larger boats and advanced electronic gear (depth sounders, loran-C navigation devices, temperature sensors). Many steelhead/rainbow move back nearshore in autumn and into tributaries to overwinter, movements documented by telemetry in fall 1982.

Lake trout proved difficult to radiotag because of their year-round preference for deeper waters than brown trout. We did tag one each in spring and fall 1981. Both remained near their release areas for several days, then disappeared into deep water nearby, never to be heard from again.

Summer netting for lake trout was highly productive. They have clearly defined temperature preferences between 43 and 55°F. Like brown trout, many lake trout occupy the thermocline zone, but 35 percent were netted within 10 feet of bottom, indicating much stronger bottom orientation than brown trout. Most lake

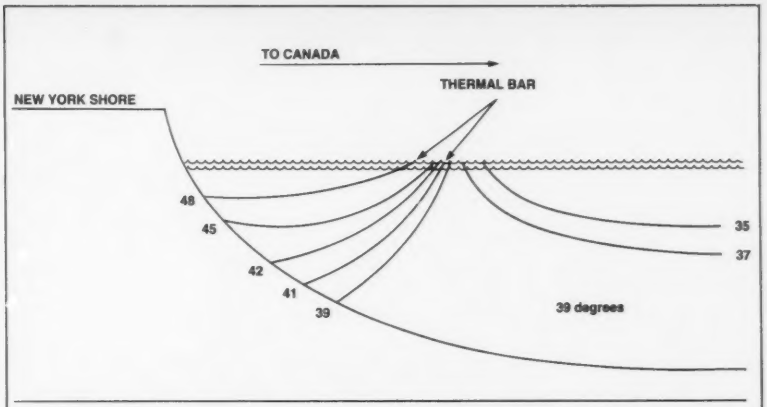
trout were netted in less than 100 feet of water, indicating that they too occupy narrow temperature preference bonds as close to shore as possible in summer. We have netted, and anglers have caught, small numbers of lake trout far offshore and close to the surface (still in preferred temperatures), indicating that a portion of the population may be somewhat pelagic and wide ranging.

We have been uanble to work effectively with coho salmon in spring or summer. They are currently rare in Lake Ontario because of very low recent stocking levels and poor post-stocking survival. Fall 1982 radiotagging studies revealed wide-ranging movements before selecting spawning streams.

Chinook salmon are the glamour fish of the Great Lakes, and a successful summer chinook fishery will vastly improve the economics of the Lake Ontario fishery. However, few chinook come nearshore in spring. Occasional nearshore strays are caught, and we tagged one such fish donated by an angler. The tagged chinook was released at 9:30 p.m., moved three miles east along shore, and swam toward mid-lake out of range by 1:00 a.m. We were unable to find the fish from Toronto to the St. Lawrence River by airplane and concluded it dispersed to deeper, open waters, a trait held in common with its cousins in the north Pacific. In fall 1982, radiotagged chinook displayed wide-ranging, predominantly westward movements in Lake Ontario before selecting spawning streams.

Because of the vast chinook stocking effort in Lake Ontario (2.7 million fingerlings proposed for stocking in 1983), summer netting has been somewhat successful, despite chinook dispersal habits. In 1981 netting within three miles of shore, chinook salmon preferred temperatures from 57-63°F in areas in and above the thermocline. Netting in 1982 supports these findings, but only occasional chinook have been netted five to 15 miles offshore, indicating there is some concentration of chinook in nearshore thermoclinal areas, at least in late summer as onshore movements in preparation for fall spawning runs begin. Thus, it appears that the dispersing habit of chinook will make offshore fishing difficult but that, as numbers in the lake increase, nearshore thermocline areas may offer improved summer chinook fishing and spur the fishery, tourism, and economic boom hoped for by the Lake Ontario communities.

Radiotelemetry and vertical gill netting, fishery research techniques new to the Great Lakes, have helped researchers learn the locations, movements, and habitat preferences of salmon and trout in Lake Ontario. Radiotelemetry shows that salmon and trout move great distances during seasons when they are nearshore; summer netting reveals that steelhead/rainbow trout and Pacific salmon are widely dispersed and far offshore, while lake and brown trout are concentrated in narrow temperature preference bands associated with the thermocline, lake bottom, and nearshore regions. Based on our experiences, we hope to design new research approaches to solve Great Lakes fishery problems and to help restore ecological and economic health to the Great Lakes region. □



Simplified springtime thermal bar and temperature gradient illustration for Lake Ontario.

Tracking truck with antenna.

Acknowledgements

This research was supported by several Research Foundation of SUNY awards to the author, NOAA New York Sea Grant Institute grants to the author and Dr. J.D. Winter at SUNY Fredonia, and various contributions from anglers' groups and SUNY Brockport. Graduate research fellows David C. Nettles and Kevin M. Parnell of SUNY Brockport and Robert A Olson of SUNY Fredonia collected and analyzed much of the information presented here for their master of science research theses. Undergraduate research assistants Joe Orzell and Frank Erardi of SUNY Fredonia and Chris Keleher, Dave Gesl, and others from both SUNY colleges provided much help in the field. Special thanks go to Ronald Salyer, who donated our tracking truck, and Michael Voiland, who helped in innumerable ways as sea grant extension agent at SUNY Brockport.

A PROBLEM CAN BE A RESOURCE:

BEACH NOURISHMENT WITH DREDGED MATERIAL

By Mark W. Mugler

On the seacoasts and Great lakes shorelines, the traditional objectives of the U.S. Army Corps of Engineers have been to meet national needs for efficient waterborne transportation and to protect life and property from coastal hazards. National legislation in the late 1960's and 1970's provided a third objective: to protect the natural environment.

In many locations the sandy material dredged from Federal navigation projects may be placed on eroding beaches. In such a fashion both navigation and shore protection needs can be met in accordance with environmental mandates and the natural laws governing coastal systems. This article reviews the development of practices and policies relating to navigation dredging, beach nourishment, environmental protection, and the beneficial use of dredged material which have made possible the use of material from navigation dredging as a resource for shore protection.

DREDGING FOR NAVIGATION

Dredging is the removal by mechanical means of material from the beds of rivers, lakes, and oceans. Although dredged material is often used by the Corps of Engineers for beach nourishment, levee construction, and creation of landfill, the principal purpose of dredging by the Corps of Engineers is for the development and maintenance of the nation's navigable harbors, rivers and waterways—the first civil works assignment of the Corps. On an average, the Corps of Engineers dredges for navigation over 300 million cubic yards of accumulated sediments each year. Approximately 80 percent of the dredged material is from maintenance at existing projects; 20 percent is from the construction of new projects. The four most common forms of disposal are deposition in the open waters and submerged lands near the dredging site, in diked containment areas, in designated ocean sites, and on beaches and riverbanks.

Mr. Mugler is a policy analyst with the U.S. Army Engineer Institute for Water Resources, a division of the Water Resources Support Center, Fort Belvoir, Virginia 22060.

DREDGING FOR NOURISHMENT

Beach nourishment is the placement, for shore protection, of sandy material on beaches and dunes or in the littoral (nearshore) zone. The sandy material used for beach nourishment may be transported from inland sources or may be dredged and transported or piped from the beds of the rivers, lakes, and oceans.

Since 1946 the Corps of Engineers has been authorized to recommend shore protection projects to Congress and to bear a portion of the construction costs for any such project authorized. Project maintenance is the responsibility of non-Federal units of government.

By 1956 beach nourishment was recognized as a potentially desirable form of shore protection. By increasing beach and nearshore elevations, nourishment replaces material removed by beach erosion, protects coastal properties from wave attack, and preserves or enhances recreation opportunities. If suitable material is located nearby, beaches may be nourished either in conjunction with or as an alternative to traditional structural measures such as groins, riprap, and seawalls. Unlike structural measures, beach nourishment creates widespread benefits as wave action distributes the material along the shoreline.

Corps of Engineers photos

Coastal features are formed by the interaction of waves and currents with coastal sediments.

Each year the Corps of Engineers dredges over 300 million cubic yards of material.

In 1956 Congress classified beach nourishment for shore protection as "construction" and consequently eligible for a Federal cost share. Since then, Federal beach nourishment plans have been implemented in dozens of locations throughout the nation. In 1976 Congress authorized the Corps to extend the nourishment period at existing Federal nourishment projects to a maximum of 15 years.

Offshore sources of material have played a growing role in beach nourishment as better information on the locations and characteristics of these sources has become available and as technological improvements have lowered costs. Material can be piped long distances using booster pumps. With the use of hopper dredges, only one set of equipment is needed for dredging, transporting, and depositing or pumping sandy material. Shallow-draft split-hull dredges such as the Corps' *Currituck* can bottom-dump material directly in the littoral zone.

ENVIRONMENTAL CONSTRAINTS

Since many methods of dredged material disposal have the potential for environmental damage in sensitive locations, the environmental protection legislation of the 1970s has had a dramatic effect on navigation dredging. Potential disposal sites are fewer, delays are longer, and costs are higher. Major environmental statutes affecting dredged material disposal

(Top) Beach nourishment with material dredged from Jacksonville Harbor, 1974.

(Inset) Material from Corps of Engineers' navigation projects has been used at over 80 sites. Pictured: Sea Girt, New Jersey.

include the National Environmental Policy Act (NEPA), the Federal Water Pollution Control Act amendments of 1972 (FWPCA), the Marine Protection, Research and Sanctuaries Act of 1972 (Ocean Dumping Act) and the Clean Water Act of 1977. These laws prohibit avoidable and unreasonable degradation of the environment.

Before enactment of these laws, the least costly method of disposal was usually selected at each dredging location, the most frequent method being deposition of the material directly into the open waters or onto the submerged lands near the dredging site. However, open-water disposal of polluted material dredged from urban industrial areas could have adverse effects on water quality, and placement of material in wetlands or productive sheltered waters sensitive to turbidity could damage biological productivity. Furthermore, in the navigable waters subject to the Clean Water Act, state law may prohibit open-water disposal otherwise environmentally acceptable under Federal standards. In some states, open-water disposal is prohibited entirely.

With fewer opportunities for unconfined disposal, the number of potential disposal sites near some dredging locations has been reduced. Noncritical dredging is often deferred while difficult disposal issues are resolved. The method finally selected is often a costly technological fix such as the construction of containment (diked disposal) areas or ocean disposal.

BENEFICIAL USE INCENTIVES

Constrained by high costs, limited funds, and environmental considerations, Corps planners and operations personnel have difficult choices to make in setting dredging priorities and locating sites for disposal. Beneficial (productive) uses of

Wrightsville Beach, North Carolina – Before and After.

dredged material can create benefits which offset some of the added costs and thereby can expand the range of choice for disposal.

Beneficial uses of dredged material include fill for beach nourishment, development of sites for ports and commercial or industrial activities, marsh creation and restoration, and even road building and construction. Since 1968 it had been Corps policy,

> "to secure the maximum practicable benefits through the utilization of materials dredged from authorized navigation channels and harbors, provided extra cost to the Government is not incurred. Such use of dredged materials will include nourishment of beaches, erosion control of river banks, and land reclamation. If it is evident during the initial planning of dredging operations that additional costs would be incurred, local interests will be given reasonable opportunity to finance the additional costs."

In 1973 the landmark Principles, Standards and Procedures for Water Resources Planning were adopted. Successors to those guidelines govern planning by the Corps of Engineers and other water resource agencies and provide the latitude to seek and evaluate beneficial uses for dredged material.

Beginning in 1974, Congress specifically encouraged such beneficial uses; one mission of the Dredged Material Research Program, authorized in that year, was to investigate productive uses. The Water Resources Development Act of 1976 authorizes the Corps to extend the economic life of existing containment sites by finding methods to reuse the diked material. The Corps is also authorized to create or restore marshes using material dredged from existing or new projects and pay up to $400,000 of the added costs. Beach nourishment is specifically encouraged in Section 145 of the act.

Today, personnel in engineer districts and divisions routinely evaluate productive use alternatives for dredged material. Industrial sites, marshes, parks, beaches, and other facilities are being developed with material from navigation projects.

Miami Beach – Before and After

NAVIGATION & NOURISHMENT

Concurrent with environmental laws and beneficial use incentives has come expanded understanding of coastal processes and systems. Consequently, the potential value of beach nourishment using dredged material is now recognized in policy and practice.

Beach nourishment is consistent with coastal processes. Coastal features such as beaches, bays, and inlets are formed by the interaction of waves, currents, and wind with coastal sediments. Unlike structural navigation and shore protection features which combat or disturb coastal processes, beach nourishment augments the natural transport of littoral sediments. Unlike disposal in the deep ocean or diked areas, the use of dredged material for beach nourishment keeps it in the littoral system. Because of the improved understanding of littoral processes, the deposition of sandy material in the littoral zone and the onshore placement of beach fill are both accepted as nourishment techniques.

Available data indicate that the environmental impacts of depositing dredged material on beaches or in the littoral zone are minimal. The biota associated with these habitats are highly adapted to environmental stress and, as such, quickly recover from periodic beach nourishment efforts.

In Section 111 of the River and Harbor Act of 1968, Congress addressed the interactions of coastal processes and sediments. Section 111 authorizes the Corps of Engineers to mitigate, at total Federal expense, the erosion effects on downdrift beaches of Federal navigation projects which interrupt the transport of littoral sediment by wave action. Mitigation frequently involves dredging the material trapped in or updrift of the navigation project and using the material for beach nourishment.

In the early 1970s the Corps, in cooperation with non-Federal sponsors, experimented with the use of dredged material for beach nourishment at Jackonsville, Florida, and Virginia Beach, Virginia.

In an average year between 1973 and 1977, the Corps dredged 128 million cubic yards of material in maintenance operations on the seacoasts and Great Lakes shorelines. As shown in *Table 1*, 10.5 million cubic yards (8.2 percent) of that material was used for beach nourishment.

In the 1976 Water Resources Development Act, Congress for the first time explicitly recognized the potential for beach nourishment using material dredged from navigation projects. Section 145 of the act provided:

> "The Secretary of the Army, acting through the Chief of Engineers, is authorized upon request of the State, to place on the beaches of such State beach-quality sand which has been dredged in constructing and maintaining navigation inlets and channels adjacent to such beaches, if the Secretary deems such action to be in the public interest and upon payment of the increased cost thereof above the cost required for alternative methods of disposing of such sand."

OPPORTUNITIES & CONSTRAINTS

By 1981 dredged material from Corps of Engineers navigation projects had been used for beach nourishment purposes at over 80 sites. Most of the nourishment operations involved the use on public beaches of material from maintenance dredging. In addition, dredged material is used at authorized Federal beach erosion control projects at Sandy Hook, New Jersey, and East Rockaway Inlet, New York. At Little River Inlet, South Carolina, material from emergency dredging is deposited on nearby beaches. In the Detroit District of the Corps at least seven erosion mitigation projects under Section 111 involve the use of dredged material for beach nourishment.

In 1981 a survey by the U.S. Army Engineer Institute for Water Resources investigated existing and planned navigation projects on the seacoasts and Great Lakes shorelines for which dredging was planned, initiated, or resumed after 1977. The survey found that dredged material from 25 percent of these navigation projects is used for nourishment purposes. Among the combined navigation dredging—beach nourishment operations identified, on-land nourishment and deposition of material in the littoral zone are used equally frequently. For five out of every six such combined dredging and nourishment opera-

TABLE 1

	Average Annual Disposal, 1973-1977	
Disposal Method	Million Cubic Yards	Percent
open water	22.2	17.3
ocean	33.3	26.0
contained	35.1	27.4
beach nourishment	10.5	8.2
other	27.0	21.1
TOTAL	128.1	100.0

tions, beach nourishment is the least-cost environmentally acceptable disposal alternative, and there is no incremental cost requiring financing by entities other than the Corps. Two-thirds of such combined operations are located in the engineer districts of Jacksonville, Mobile, Los Angeles, and Detroit.

Despite its prevalence, beach nourishment cannot be considered a panacea for dredged material disposal ills. For three out of every four navigation projects the dredged material is not a practical, cost-effective, and permissible source for beach nourishment. Most frequently, the material is too fine-grained to be effective for shore protection. Other constraints are excessive cost, impermissible environmental effects, and technical limitations.

The following listing shows the approximate distribution of decisive constraints:

- 34% Grain size of the dredged material (e.g. mud, clay, silt, rock) is inappropriate for beach nourishment.
- 10% Mobilization, material transport, piping and/or demobilization costs are excessive.
- 8% Water quality, turbidity, and fish and wildlife impacts are unacceptable under Federal standards.
- 6% Technical limitations. These include shore features and uses which are unsuited for nourishment, the existence of preferable source of material, wave or current conditions that are hazardous to equipment, and anticipated adverse effects on navigation and water uses.
- 5% Nourishment is not needed or is of little benefit.
- 4% Project-specific institutional constraints prevent nourishment.
- 3% A suitable dredge and/or suitable equipment are unavailable.
- 3% The non-Federal project sponsor prefers another beneficial use for the dredged material.
- 2% State law prohibits beach nourishment acceptable under Federal standards.
- 75% *Total:* use of dredged material from navigation projects is impractical, not cost-effective, and/or impermissible.

Opportunities to expand the use of dredged material for beach nourishment are limited. Problems of equipment availability may abate over time, and some project-specific institutional constraints can be remedied by better coordination between the Corps and non-Federal interests. Further improvements would require changes in law or technology.

FROM PROBLEM TO RESOURCE

Under the proper circumstances the use of dredged material for beach nourishment not only contributes to the development and maintenance of waterway transportation but also provides hazard reduction and recreational benefits consistent with environmental mandates and the material laws governing coastal systems. Reinforced by Congressional enactments between 1956 and 1976 relating to beach nourishment, environmental protection, and the beneficial use of dredged material, the Corps of Engineers has learned to capitalize on suitable opportunities to nourish beaches with dredged material. For perhaps one in every four Corps' dredging projects on the seacoasts and the Great Lakes, involving over 10 million cubic yards of dredged material each year, a potential problem can be a resource. □

View of sand being pumped on beach during early stage of operation.

Events, Deeds & Deliberations

NEW SYSTEM FOR SUMMARIZING NATION'S WATER RESOURCES

Interior Secretary James Watt has announced steps to implement a system to produce an annual national water summary that will make water resources information more readily available and useful to policy makers and managers at local, state, and national levels.

"Nothing can be more basic than water resources in planning the future growth and health of our nation," Watt said, "yet past assessments of the adequacy of our nation's water resources have been too infrequent and too complex to be generally helpful to decision makers. Water resources policy makers and managers at all levels of government need information about water availability, quantity and quality, and the problems associated with the use of our vital water resources.

"In keeping with administration policy that the responsibility for water resources management rests with the states, the Interior Department has an important role in providing state and local agencies with current, accurate evaluations of water conditions and critical water problems," Watt said.

To accomplish this goal, the Secretary has directed Interior's U.S. Geological Survey (USGS) and the Office of Water Policy (OWP) to take the following steps:

- The USGS will prepare annual national water summary reports targeted for initial publication in October 1983. The initial report will summarize national water conditions, and subsequent annual reports will focus on selected water problems. The OWP will coordinate with state and local decision makers to ensure that the information presented in the reports is responsive to the users' needs.
- The USGS will develop a water resources information system that will contain summary data about the nation's water resources. The new information system will be used in conjunction with existing water data bases to retrieve, analyze, and display information about water resources conditions and to track changes over time. The OWP will coordinate responses and suggested improvements to the system from policy makers and managers.
- Using data supplied by the USGS and other agencies in the public and private sector, OWP will work with state officials to identify critical water problems. The Interior Department will then respond to specific local needs and requests and develop programs to provide needed assistance.

"I am directing the Office of Water Policy to seek comments from agencies and groups at the national, state, and local level about the criteria, format, and goals of subsequent annual reports," Watt said. "We will also work closely with state and local agencies in the development and implementation of the information system, because they will continue to be the people most involved in water resource development and management.

"At the same time, I am directing the USGS to begin working immediately with OWP to put together a demonstration of the potential of the new water resource information system," Watt said. "I expect by midsummer that they will be able to develop a test case and demonstrate with tabular, graphic, and map dis-

plays how the system can be applied to the analysis of water resources information.

"This new system should eventually have widespread application in the preparation of water assessments and studies by other agencies and will markedly enhance many of the hydrologic programs of the USGS, including the preparation of the annual national water summary.

"Because development of the information system and preparation of later assessments will also require the talents and cooperation of many offices and individuals, I have asked for the full support of all Interior Department bureaus and offices in making this critical assessment of water conditions viable and effective," Watt said.

As the nation's largest water resources data collection agency, the USGS currently monitors the quantity and quality of the nation's water resources at about 44,000 sites in cooperation with more than 800 Federal, state, and local agencies and conducts hundreds of water resources studies annually. The USGS also maintains an index to existing water resources information gathered by 400 other agencies and serves as the lead agency in coordinating the water data acquisition activities of all Federal agencies.

NATION USING MORE THAN 450 BILLION GALLONS OF WATER A DAY

As of 1980, the United States was withdrawing a record high total of 450 billion gallons of water a day from surface and groundwater sources to meet the needs of public supply, industry, irrigation, rural, and commercial users. This amounts to an average of about 2000 gallons per person per day, according to a recently published report of the U.S. Geological Survey (USGS), Department of the Interior.

The latest USGS summary of the nation's water-use patterns—the seventh in a series of reports compiled every five years since 1950—notes that the nation's total water use has more than doubled in the last 30 years. The report emphasizes, however, that although the nation is now using more water on a daily basis, the rate of increase in water use was only eight percent during the 1975-1980 period compared to a 12 percent increase during 1970-1975.

According to Wayne B. Solley, hydrologist at the USGS National Center, Reston, Va., and senior author of the report, "It is difficult to pinpoint the exact causes for the slowdown in the rate of increase of national water use.

"The slowdown probably reflects a combination of factors, including the decline in the economy, regional droughts that restricted water use, more prevalent reuse of water and perhaps the improvements in the accuracy of our water-use estimates," Solley said. "Despite the slowdown, we can be rather certain that overall water use will continue to increase in future years and even at a reduced rate will require careful management and continuing reappraisal of available resources."

Solley said that improvement in the accuracy of summary data results from a huge increase in the amount of data collected at thousands of locations across the country, an improved technical capability to make more detailed evaluations of existing water data, and the increased participation of individual states aiding in developing the national water-use information program that began in 1977.

The USGS report reveals that:

- Although the average use of freshwater in the U.S. is about 1600 gallons per capita per day, the use varies greatly from state to state, ranging from a high of 19,000 gallons per capita per day in Idaho to a low of 180 gallons per capita per day in Rhode Island. High per capita values are characteristic of thinly populated states having large acreages of irrigated land.
- California withdrew more water than any other state—about 54 bgd (billion gallons per day), or more than twice as much as either Florida or Texas, the next largest users. Four states—California, Florida, Texas, and Idaho—withdrew 25 percent of the water used in the United States.
- The total quantity of freshwater consumed—that is, water made unavailable through such processes as evaporation and transpiration or incorporated into products or crops for subsequent possible withdrawals—averaged 100 billion gallons a day in 1980.
- More water was withdrawn for industrial uses than for any other category of off-stream use. In 1980, industry used about 260 bgd, including about 72 bgd of saline water (water containing more than 1000 milligrams per liter dissolved solids). About 83 percent of the water withdrawn for industry was used in the generation of thermoelectric power.
- Irrigation ranks second in off-stream water withdrawals in the nation—150 bgd or 170 million acre-feet per year—and is by far the greatest consumer of water (83 bgd or 93 million acre-feet per year).
- The amount of water consumed by irrigation far exceeds the consumption of all other categories combined: 7.1 bgd for public supplies; 10 bgd for self-supplied industry; and 3.9 bgd, for rural uses.
- Over 90 percent of the irrigation water was withdrawn in the western United States. In contrast, almost 90 percent of the industrial water was withdrawn in the eastern United States.

Solley said, "Overall, the nation as a whole has ample supplies of water. For example, the average annual streamflow in the coterminous (48) states—one simplified measure of the total potential water supply—is about 1200 billion gallons a day, or about two and a half times our present water use. Moreover, this estimate of potential water supply does not include groundwater supplies, which are even larger.

"This apparently favorable balance of water supply nationwide, however, may bear little resemblance to the actual supply-demand situation in a local area or for specific users who face water supply shortages because of such factors as varying amounts of precipitation, quality problems, or limited ability for reuse of water.

"Thus some regions already must cope with water shortages of varying intensities and must face continued 'deficit spending' in their water budgets: using more water each year than is naturally supplied. Our water resources, therefore, must be carefully managed, protected, and conserved to assure adequate supplies of good quality for future generations," the USGS spokesman said.

The 64-page report, containing tables, maps, and illustrations showing data by individual states and by the 21 major water resources regions of the nation, is titled "Estimated Use of

Water in the United States in 1980," and is published as USGS Circular 1001. Copies may be obtained free on request to the Branch of Distribution, U.S. Geological Survey, 604 South Pickett St., Alexandria, Va. 22304.

OPINION NARROWS FEDERAL CONTROL OF WATER ON BLM LANDS

Interior Department Solicitor William H. Coldiron has repudiated a 1979 interpretation by a previous solicitor of a longstanding executive order which withdrew springs and waterholes on Bureau of Land Management (BLM) acreage. Coldiron's new opinion holds that the right to use the water for any purpose other than for human and animal consumption must be obtained under state law.

The effect of Coldiron's ruling is to limit Federal authority and reassert the primacy of state law in localities scattered across the rural west where the executive order, issued in 1926, is applicable.

The 1979 legal interpretation overturned by the opinion had viewed the executive (presidential) order much more broadly, asserting that it also intended to reserve water for purposes such as growing crops and for flood, soil, fire, and erosion control.

The homestead laws still in existence in 1926 allowed claimants to settle and patent parcels of vacant unappropriated public domain. By acquiring title to Federal lands surrounding important springs and waterholes, claimants could gain effective control of much larger arid areas surrounding them. The executive order established a general withdrawal known as Public Water Reserve No. 107, shutting off new land claims near important springs and waterholes and reserving the water for public use.

The Colorado Supreme Court, in a recent decision, found that the intent of the executive order was to prevent monopolization of vast expanses of the public domain through control of water sources necessary for use of the surrounding public lands. The state court found, however, that there had been "no intent to reserve the entire yield of public springs and waterholes." This ran counter to the 1979 solicitor's opinion, which held that all the waters were reserved for various uses.

The new Coldiron opinion agrees that the anti-monopoly intent did not extend to total Federal control of these strategic water sources. It concludes: "The right to use water from these water sources for any other purpose (than animal and human consumption) must be obtained pursuant to state law because those other purposes do not come within the reserved water right. The entire flow or quantity of water in these reserved sources was accordingly not reserved unless necessary for the primary purposes—a fact which must be determined on a case-by-case basis."

In 1981, Coldiron overturned another section of the 1979 opinion when he held that there was no such thing as a Federal non-reserved water right. His ruling meant that Federal land managers would have to take their place in line with other water users in state proceedings to assert water rights not specifically reserved to the Federal government. The Justice Department later made this ruling applicable to all Federal agencies.

Interior lawyers emphasized that the latest Coldiron ruling is applicable only to BLM lands and will not affect water sources or stream flows in national parks or other special categories of Federal lands.

MICHIGAN SCIENTISTS USE MICROORGANISMS FOR CHEMICAL CLEANUP

A method of using microorganisms found in lake sediment and sewage sludge to break down certain toxic chemicals is being investigated by two Michigan State University scientists.

The research focuses on halogenated aromatic compounds—a chemical family that includes such environmental pollutants as PCB, PBB, and dioxin. The Environmental Protection Agency has placed dioxin at the top of the list of compounds most acutely toxic to humans.

In studies conducted by James Tiedje, MSU professor of crop and soil sciences and microbiology, and Stephen Boyd, assistant professor of crop and soil sciences, anaerobic microorganisms have successfully metabolized chlorinated phenols, widely used industrial chemicals, and halogenated benzoates, used in herbicides.

For reasons not fully understood, anaerobic organisms from both sediment and sludge can remove chlorine from the aromatic ring structure of these chemical compounds, rendering them vulnerable to disintegrat. ı. This dechlorination process occurs in the absence of oxygen—in anaerobic conditions. Little work has previously been done with anaerobic microorganisms because of the difficulty of maintaining oxygen-free experimental environments.

Tiedje and Boyd are attempting to learn more about the composition of the microorganisms and the environments in which they live. Their long-term goal is to identify genetic components of the microorganisms responsible for breaking down the haloaromatic compounds and using the genetic material to create new organisms to clean up chemical wastes—a kind of science fiction scenario the scientists say could become a reality.

The MSU researchers have yet to determine whether the anaerobic biodegradation process is effective with the more complex classes of chemical compounds such as dioxin and PCB. More intense investigations will be required for these chemicals, but the work could produce tremendous benefits.

"Our research has the potential of developing a treatment method for compounds there is currently no way of treating," Tiedje says.

WORLD CONSERVATION GROUP FORMED

Formation of a World Association of Soil and Water Conservation was announced in January.

The new association will seek to encourage the wise use and conservation of soil and water resources worldwide. Its members will include scientists, professional conservationists, and policy makers.

Initially, the association will operate under the auspices of the Soil Conservation Society of America. SCSA will maintain membership records for the association and will publish a newsletter for the group.

In addition to publishing a newsletter, the world association will seek to sponsor a biennial conference, assess soil and water conservation needs in nations throughout the world, work for the adoption of sound soil and water conservation policies, encourage research and demonstration projects on soil and water conservation problems, and work with other worldwide conservation organizations and agencies in support of mutual interests.

☆U.S. GOVERNMENT PRINTING OFFICE: 1983—405-428

To the Readership of WATER SPECTRUM

After thorough analysis and much soul searching, we have decided to terminate publication of Water Spectrum. *The decision was not easy.* Spectrum *has earned a reputation for excellence during its 13 years of existence. The magazine holds awards from the Society for Technical Communications, the National Association for Government Communicators and the Printing Industries of Virginia. In addition the* Spectrum *staff have received many unsolicited letters of praise and support from all levels of government, academia and the private sector citing the magazine's credibility and its informational and educational value.*

Given the high esteem in which Spectrum *is held, you may well wonder why we have decided to cease publication. Two main reasons led us to our decision. The first is economic. From a press run of 16,000 copies per issue, slightly over 2,000 copies go to paid subscribers. This ratio has been fairly constant through the years. The increase in paid subscriptions necessary to offset overhead has never materialized. Consequently, the continued publication of* Spectrum *cannot be justified when viewed from the standpoint of conservative management of scarce dollar resources.*

The second reason is more subjective. We believe that Spectrum *has accomplished most of what it set out to achieve. Its purpose was to provide a forum for what were over a decade ago emerging and little understood critical environmental issues associated with water resources development. Today, a vast body of knowledge is available on the topic and a host of technical publications continue to expand our horizons. Consequently, the need for* Spectrum *has diminished over time.*

We thank you for your support of Water Spectrum. *A special expression of appreciation is extended to those of you who took the time and effort to prepare articles for publication or sent us words of encouragement and advice through the years. For in the final analysis,* Water Spectrum's *excellent reputation is nothing more than a reflection of a dedicated readership.*

J. K. Bratton
Lieutenant General, USA
Chief of Engineers

WRSC-B
DEPARTMENT OF THE ARMY
U.S. ARMY CORPS OF ENGINEERS
WATER RESOURCES SUPPORT CENTER
FT. BELVOIR, VA. 22060

OFFICIAL BUSINESS

POSTAGE AND FEES PAID
DEPARTMENT OF THE ARMY
DoD-314

U.S.MAIL

CONTROLLED CIRCULATION RATE

ADDRESS CORRECTION REQUESTED
Forwarding and Return Postage Guaranteed

John S. Tilney, Jr.

An overview of rafting and its effects is needed, especially considering the prevalence of the activity on scenic rivers in primitive woodland environments. *See "Managing Rafting Rivers," on page 10.*

THIS JOURNAL CEASED PUBLICATION WITH
VOLUME 15, ISSUE 1, (SPRING 1983).

C 32